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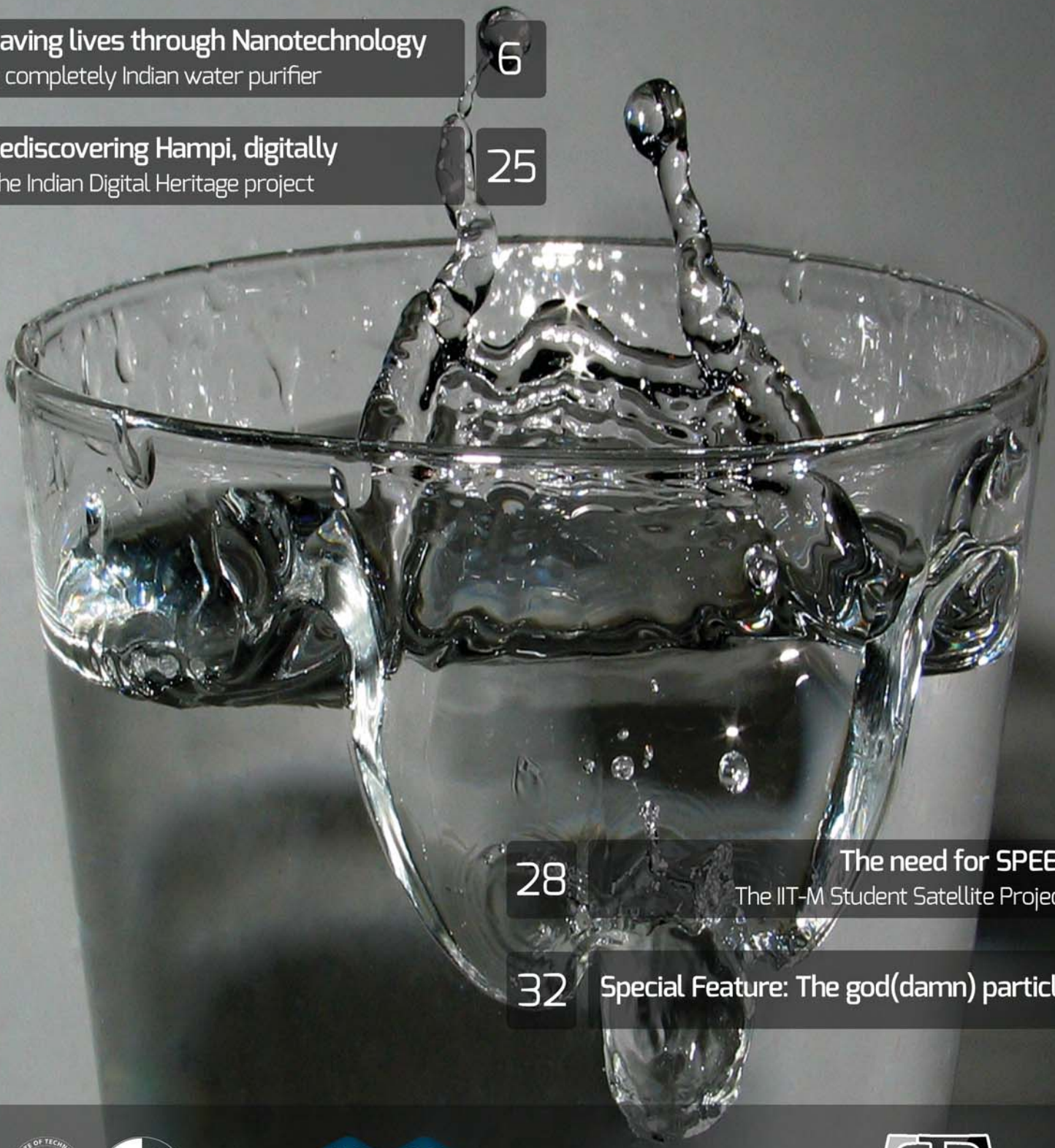
Immerse

In association with GE imagination at work

Edition 2



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Message from the Dean, Academic Research

Dear Friends,

Wish you all a very happy and prosperous 2014.

This is the best time of the year in Chennai, what with the most comfortable weather, the musical season and a festive mood prevailing at IIT Madras. The research community will use this to rejuvenate themselves for the tasks ahead. It is also *Shaastra* time and I am happy to note that this time *Shaastra* is bringing together research scholars from all the IITs together. This will help to catalyze an exchange of ideas, a sharing of problems and a drawing of inspiration from each other. I am sure all of us will take this opportunity to get excited about diverse approaches to research work taking place across the country.

This is also an occasion to look back and introspect at ourselves, both as individuals and as an institution. On the institutional side, 2013 has been a year of change in the research arena at IIT Madras. In the month of February, a special Senate meeting was held and for the first time in the history of IIT Madras, the entire meeting was devoted exclusively for discussion of the research agenda. In this meeting we accepted the recommendations of the research task force which suggested sweeping changes with respect to the initiatives and norms for research-related activities. IIT-M is the first institute in the country to introduce rights and responsibilities for research scholars. We have been very proactive in implementing the recommendations of the Kakodkar Committee, which has seen a dramatic raise in the number of Ph.D and M.S scholars in the campus. New features such as Direct Ph.D. and Interdisciplinary Ph.D. are going to become the landmarks of our research programme in the days to come. In recent times, we have taken big steps towards revamping the research safety policy and enhancing the research infrastructure. Our institute is moving towards a comprehensive policy of research performance evaluation of departments, groups and individuals within a very short time, and towards suggestions for corrective measures based on these evaluations.

Research, my dear friends, is a creative activity. Although there are some grammatical lessons to be learnt, no one can teach how innovation can be done. It does, however, require the right kind of resources (both physical and human), a dynamic ambience and a proper system of evaluation, as well as a corrective system. Let us hope that in the days to come we will be able to meet the above requirements adequately, which will elevate us to the highest level internationally. At the same time, we can contribute towards solving the problems facing our nation and our society.

If you are at IIT-M, you deserve the best, but you also need to perform at the highest level. Let us hope that we can do that in the days to come.

With best wishes,
Prof Sarit K. Das
Dean, Academic Research

Message from the Research Affairs Secretary

Immerse, the name of this magazine, is a word that aptly describes one of the essential features of doing research. Fruitful research arises out of complete immersion in a subject. At the same time it is important to be able to relate one's research to everyday life and to be able to express its wonder and significance to everyone.

The Fifth Estate in association with *Shaastra* has put together *Immerse* to help researchers of IIT Madras communicate their research in a simple, yet lucid, manner. We hope that these articles will inspire and inform not just fellow researchers, but the wider community of teachers and students, including undergraduates and school students. We also hope that it encourages more students to join IIT Madras and take up research.

I would like to congratulate *The Fifth Estate* and the *Shaastra* team on bringing out the second edition of this research magazine. I'm sure all of you will enjoy reading it.

Thank You,

Oswald Jason Lobo
Secretary (Research Affairs)

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GE imagination at work

Design, Conceptualization and Production: Nithyanand Rao and Vishakh Hegde

Cover Image Credit: Roger McLassus, via Wikimedia Commons

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Nithyanand Rao

Editor-in-Chief

From the austere mathematical beauty of the equations that prophesied the Higgs boson to the sublime, eternal art and architecture of Hampi, science and art have something in common: what breathes life into them are stories. Stories we tell ourselves and each other about who we are, what we think the natural world is like, and why it is worth studying and appreciating. From the knowledge we accrue through these stories, arises ideas of practical value.

Science and technology being the engines of the globalized, modern economy, such stories are vital in what they convey, even beyond their necessity for material progress: a shared humanity that is perhaps best exemplified by the international nature of the scientific enterprise.

IIT Madras is one of the centres of learning and research which enjoys an international reputation for excellence. This edition of the research magazine, re-christened as *Immerse*, which stands for **I**IT **M**adras **M**agazin**e** on **R**esearch in **S**cience and **E**ngineering, hopes to present you with a glimpse of the diverse nature of research at this institution – from abstract theoretical research to innovations which apply basic science in solving everyday problems.

We are grateful to all the faculty members and research scholars who generously gave us their time in talking to us about their research. On behalf of our team, I hope you enjoy reading the stories in the pages ahead as much as we have enjoyed putting it together.

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The research projects featured in this magazine showcase but a sample of the research being carried out at IIT Madras. They are not necessarily representative of the research activities at specific departments, or IIT Madras as a whole.

Academic Research: An Interview with the Dean

By Shruti Badole

Dr. Sarit K Das, who assumed office as the Dean, Academic Research in early 2013, speaks to Shruti about the research scene in the institute and the steps he's planning to take to encourage research.

Could you give us an overview of your plans as the Dean, Academic Research, of IIT Madras?

IIT Madras is no longer only an undergraduate institute. 55 percent of the student population comprises postgraduates. 35 percent of the students are pure research students. There are about 1,700 Ph.D. students and about 800 M.S. students here at IIT Madras. This is a huge number. This changes the entire fabric of the institute. Over the years, it has happened that the research community has remained segregated. It perceives itself as a small community, with the institute mostly being dominated by undergraduates and M.Tech students. This perception has to change. The research community has to realize that it is a very important part of the institute.

The government is looking at having IITs as the top research universities. It aims to enhance the total number of Ph.Ds from 1,000 to 10,000, in all the IITs put together, by 2020. For this to happen, the research scholars themselves should come out of their shell and we have seen in recent times that it has started happening. Recently, a Research Scholars' Day was organized. The research scholars are coming out with their difficulties and demands, which is a good sign. The important thing is that non-research scholars should also sense their perception; the B.Tech students should also think that they can learn a lot from the research work which is going on in the institute, the M.Tech students should realize that some of them could even change their programme to Ph.D. There should be interaction between the research community and the course-based students. But this is something the students have to do.

The institute, on its part, needs to take some initiatives, and these are what we have already started doing. Firstly, by inviting quality research scholars; for the first time, we have started an outreach programme in various cities of the country. We have met the students of various reputed institutions and told them about the possibilities of joining as research scholars at IIT-M.

We have invited the GATE toppers and straight away offered them Ph.D. admissions. Our M.S.–Ph.D. programme has undergone a complete overhaul. Before taking up the post of Dean, AR, I headed the research task force and hence it was easy for me to implement the recommendations in which we have changed the rules of M.S.–Ph.D. programmes quite a lot. Now, rather than having year-based evaluations, we have event-based evaluations. We have started interdisciplinary Ph.D. programmes, which will be governed centrally.

We have also made an institutional mentoring committee to mentor the young faculty members. This is very important because the young faculty members are the ones who are going to take up the baton of research in the coming days. The committee comprises all the Bhatnagar awardees (there are five of them at IIT Madras) and a couple of people working in IISc, Bangalore (alumni of IIT Madras). So, the institute is trying to get better people in the research wing, to mentor the faculty and the students well, and also trying to create a very good infrastructure for the research scholars.

What do you think about the present postgraduate research scene?

I think the research scene in M.Tech has improved. Today, a large number of M.Tech students publish papers in journals, while ten years back, publishing a research paper while doing M.Tech was very rare. Also, it was rare to find postgraduates going for higher studies. This scene has changed a lot over the years. People have started converting their programmes from M.Tech to Ph.D. The number of Ph.D. students is increasing and the quality of work is also improving. I see a very bright future.

There is a general feeling that undergraduate students are not very interested in research. Would you agree?

In my opinion, looking at the number of students opting for non-technical jobs, this perception is right. Earlier, the complaint used to be about IIT

students going abroad. I have taught a batch wherein 67 out of the 85 students went abroad after their education at IIT. I was really asking myself the question: who and what for am I teaching? I think today the scenario has changed, considering only about 15 percent of the students go abroad and the others take up jobs, which is good for the country. But a question remains: what kind of jobs? Jobs in the finance and management sectors dominate, and this trend is reflected in the decrease in the amount of research work done. This trend of the best students not going for research is alarming. If there is brain drain, it's bad; but if there is "brain in the drain," it's worse! In India, the present scenario is: where you need intelligent people, you don't have them, and where you have them, you don't really need them!

The IIT Madras Research Park is the first university-based research park in India. In what ways do you think students can use this resource more?

The Research Park is a very important step that IIT Madras has taken. In fact, the other IITs are now replicating this model. We have the second phase coming up: the second tower is going to be built in the Research Park. It has already incubated certain companies which are doing a wonderful job of taking the technology developed inside IIT Madras to the market. Many of the technologies are related to things like healthcare, which are directly related to the public services. We have developed a mobile eye-surgery unit in collaboration with Sankara Nethralaya. It has been extremely successful and the government is now going to use this as a model to do cataract surgeries in rural areas. Through the Research Park, we are doing excellent work. In fact, when it comes to socially relevant projects, IIT Madras probably tops at the moment. But unfortunately, a very small fraction of the students and faculty know about the good work that is happening.

We are aware of this and are planning to take steps so that our students, through the Research Park companies, can do some good work.

Are there any grants given by IIT Madras for students to take up research?

IITs are given block grants. How to spend these grants depends on the IITs. So there's no special grant devoted to research activities, but we do invest in that area. Take the example of the Centre for Innovation (CFI), where so many of our students work. It's better to keep such a model separate from the curriculum, because there's a saying that if you want to kill a student's interest in anything, put it in the curriculum! I think if you do research as fun, and not as a part of the curriculum, it will be more exciting, particularly for the younger people. Funding is not an obstacle for research at IIT Madras. The main concern is how to draw more students into it. We need to take more initiatives like the CFI to bring the undergraduates and the Master's degree students to the field of research.

What would be your message to the students?

My message is only one: Please understand that you are in the 21st century. The days of mugging from books and vomiting into answer sheets are gone. Today information is available at the click of a mouse; nobody looks at a graduate from IIT for information. It's your understanding which gives you an edge to innovate. The ways and methods you are learning, which will help you to innovate further, are going to be very important. So, learning how to innovate is going to be much more important than learning a subject. Everybody, including the undergraduates, postgraduates and research scholars should concentrate on how to innovate, how to think about new concepts and how to put them in place. Whether it is through CFI, projects or even informal associations, everyone at IIT Madras should get some hands-on research experience.

Walking on Water

By Nithyanand Rao

Arsenic poisoning causes several illnesses from skin diseases to cancer. Six million people are chronically exposed to arsenic-contaminated water in one state alone: West Bengal.

Convinced that nanotechnology holds the key, Prof. T. Pradeep and his students accepted the challenge of developing a sustainable and affordable solution for purification of the contaminated water. The team of young researchers worked relentlessly for several years to develop a suitable nanocomposite material that effectively filters out arsenic. It is also an environment-friendly material that's not difficult to produce and is cost-effective.

Extensive experiments confirmed the efficacy of the technology in converting arsenic-contaminated water to crystal clear drinking water. And recent field trials conducted in West Bengal showed extremely encouraging results. Now, efforts are on to take this technology to the affected people on a large scale.

THE RESEARCH TEAM ON WATER.
FROM LEFT TO RIGHT: SEATED IN THE FRONT ROW - Amrita Chaudhary, Udhaya Sankar, Anshup, Swathi Chaudhari;
IN THE BACK ROW - Swati J R, Sahaja, Prof. Pradeep, Anil Kumar.

PHOTO CREDIT: Prof. T. Pradeep

Professor Thalappil Pradeep sat bolt upright in his chair and leaned forward, eyes alight and impassioned. He grabbed an imaginary scientist, shook him vigorously, and exclaimed, his voice urgent: "An average Indian could come and ask: 'Have you solved any of my problems?' Take one IIT and ask, what problem did it solve?"

He leaned back and said more softly, a sense of quiet satisfaction on his face, "It is one of the motivations for me, to do something."

Of all the problems that can be solved using basic science, he has picked one which is most urgent: water. The Government of India has, in fact, prioritized the addressal of the water quality problem, particularly that of arsenic contamination of drinking water. This is the case in parts of West Bengal, where water is drawn from deep borewells, chronically exposing an estimated six million people to arsenic toxicity, which causes skin lesions, lung, bladder and skin cancer, and even cognitive deficiencies in children.

The nanoparticle-based water filter developed in Prof. Pradeep's lab requires no electricity to run, is adaptable to local conditions – the variations in the quality of water and the nature of its contaminants – can be scaled-up from meeting the requirements of a household to that of an entire community, needs little or no maintenance, and is environment-friendly. And affordable. For Prof. Pradeep, that last point is the key: "We defined affordability as 5 paise per litre of clean water delivered at home. Can you give arsenic-free water at 5 paise per litre delivered at home on your kitchen table? That's what these materials can do."

The provenance of Prof. Pradeep's work on water filters goes back more than ten years. While working on nanomaterials, he asked himself what, if anything, these tiny particles could do to solve the problems of everyday life. That was in 2002.

He and his students then developed a nanoparticle-based water filter to remove pesticides, which as Prof. Pradeep points out proudly, "became the first such technology in the world to get commercialized." The filter consists of silver nanoparticles impregnated on alumina, which upon reacting with the halocarbons in pesticides, breaks them down into metal halides and amorphous carbon. This was licensed to Eureka Forbes in 2004, which started producing water filters incorporating this technology in 2007. "We are getting a very tiny royalty, to the institute," says Prof. Pradeep.

But that did not satisfy him. After all, there are contaminants other than pesticides – heavy metals like iron and arsenic, and harmful microorganisms – in groundwater.

He holds up a small plastic vial containing a dark powder and continues, "It so happened that we had produced several materials and one of them was quite good when it comes to handling arsenic. So this is that material."

That material is iron oxyhydroxide in nanoparticle form. "In a composite cage," Prof. Pradeep reminds me. "We have a cage which is made with iron oxyhydroxide, which is now connected with polymers – biopolymers – in this case, chitosan. This whole thing is made in water at room temperature. And that material is one in which you can get arsenic ions to get in. But bigger particles will not. So as a result of that inherent affinity of this oxyhydroxide to arsenic, arsenic is scavenged." All this without the use of electrical power.

For antimicrobial action, aluminium oxyhydroxide nanoparticles are used instead of those of iron oxyhydroxide and the resulting cage is embedded with silver nanoparticles. Aluminium oxyhydroxide sheets of about 20 nanometres – one nanometre is a billionth of a metre – in length and about 5 nanometres in thickness are formed in solution. "That is the inherent nature of this material," explains Prof. Pradeep.

"Now, if you take a stack of these, with polymers connecting them so that there are cages of them getting formed, what we have devised is this composite." The chitosan ensures strong binding of the nanoparticle surface to the matrix. It also addresses one of the key challenges, namely, preventing the nanomaterial surface from being covered by deposits.

The water-filtering unit which Prof. Pradeep's lab has developed, was recently field tested in the districts of Murshidabad and Nadia in West Bengal. The groundwater in some parts of the district contain up to 300 parts per billion (ppb) of arsenic ions, which can be of two kinds: those that have lost three, or five, of their outer electrons. The World Health Organization guidelines, however, set a safe limit of 10 ppb and the national limit is 50 ppb.

"We installed two of those units and there was a very enthusiastic district collector. Without us knowing about it, he was actually collecting samples and monitoring. He told us some months later that 'Hey, this is great.' Of course, we were getting data, but he was excited that arsenic was not even detected. So he was quite happy about it," says Prof. Pradeep with a smile. The successful trials meant that it has now become a project of the state government. "They are putting up 2,000 units, each unit for 300 people – so it will cover 6 lakh people. That is under the installation process. It will take 18 months to finish."

Using inputs from these field trials, the design was improved. "And finally you got the AMRIT – Arsenic and Metal Removal through Indian Technology," says Prof. Pradeep proudly.

The water-filters can be customised to filter out almost any contaminant – lead, iron, or bacteria such as E.coli – just by having another filtering unit containing suitable nanoparticles. The lab has developed a range of nanomaterials which can selectively remove each impurity. Bacteria, for instance, can be destroyed using silver nanoparticles in the size range 10–20 nm because they release trace quantities of silver ions in water, whose concentration (40–50 ppb) although sufficient to destroy microorganisms, is not toxic to humans.

Similarly, manganese dioxide nanoparticles can filter out lead. Thus, an all-inclusive drinking water purifier can be built that functions without electricity. All this at Rs. 130 per year per family, assuming a daily water consumption of 10 litres.

The antimicrobial unit can filter up to 1,500 litres of water before needing re-activation of the silver nanoparticle surface, for which there are simple methods available: one can heat the matrix, or use diluted lemon juice. This re-activation can be done until the requisite silver ions cannot be released from the matrix any further.

However, Prof. Pradeep cautions: "There is no solution which is a complete solution. The problem of water is so vast, so big, every solution has a role. Moreover, water itself is so diverse. That is, your well water is different from your neighbour's well water. There is a lot of diversity in this, the chemistry is different. So therefore, there is a need for diverse products."

Prof. Pradeep acknowledges the support he has received from funding agencies. His lab, the Department of Science and Technology (DST) Unit on Nanoscience, has been designated as a Thematic Unit of Excellence on Water Purification using Nanotechnology under the Nano Mission of the DST. Visitors to the lab are greeted by a serene figurehead of the Buddha. Inside, the routine is to remove one's footwear and use one of the "lab chappals" kept on a separate, neatly name-labelled footwear stand. The walls give testimony to the success and worldwide acclaim that Prof. Pradeep's lab has achieved. His friend and mentor during his postdoctoral stint at Purdue University, Prof. Graham Cooks, writes of how Prof. Pradeep "has established a school of molecular materials which is surely without an equal in any other single investigator lab."

"When I was a student I didn't really know what the excitement of science was. Today, science possesses me. You get engulfed into it, you become so passionate about it," says Prof. Pradeep. That passion has been duly recognized on many occasions.

PHOTO CREDIT: Prof. T. Pradeep

The final prototype of the AMRIT water-filtering unit.

Among the photos which adorn the walls are those of Prof. Pradeep receiving the B.M. Birla Science Prize from the then President of India, Dr. APJ Abdul Kalam, and of receiving the Shanti Swarup Bhatnagar award – India's highest science award – from the Prime Minister, Dr. Manmohan Singh. "But recognitions apart, what is more important is to do meaningful science," observes Prof. Pradeep.

The success comes from hard work by Prof. Pradeep and his students. "I've been fortunate to have students who are so passionate about it. This passion is what drives. But nobody can fully understand the effort involved in making a student," he points out.

One of those students is Anshup. A 2005 B.Tech Chemical Engineering graduate from IIT Madras, he has a disarming smile and a firm handshake that puts you at ease immediately. Behind all the charm lies a strong will, and an ability and willingness to work extremely hard at something he is passionate about. A busy man Anshup is, and we meet up on his way home from a long day at work.

"The last six years or so have been very fascinating. The materials we have developed are new, the properties which we have found are very new, and the way these materials have been applied are also new," says Anshup. "We spent a lot of time in developing these materials. We have about 20 Indian and international patents," he says, counting them off, and beaming with the pride of a man who is reaping the fruits of his toil. "And we are continuing to work on more," he adds matter-of-factly.

Anshup is one of the co-founders – along with Udhaya Sankar, who holds a Master's degree in Nanoscience from Madras University, and Amrita Chaudhary, a B.Tech in Chemical Engineering from IIT Madras, the three big movers, as Prof. Pradeep describes them – of InnoNano Research, a company incubated at IIT Madras and established to manufacture the nanomaterials specifically for community projects such as the one in West Bengal. Prof. Satish Kailas of the Indian Institute of Science, Bangalore, has been providing advisory support for this venture.

The state government of West Bengal has committed to setting up 2,000 of the arsenic-filtering units. "We're doing it in eight phases. Now, phase one is complete and we're going to phase two. We have prepared ourselves to manufacture close to 40 kilograms of the nanomaterial everyday," says Anshup excitedly. They have set up a plant for this purpose at Ambattur, just outside Chennai city. "This plant is spread over an area of close to 10,000 square feet. It is pretty huge," says Anshup. "The plant is functional. Once it's fully ready, we can manufacture as much as 200 kilograms per day of these nanoparticles."

And then his voice trails off. "It has taken nearly six years to get to this stage," Anshup reminds me again. "We've gone through all the pains that one can imagine. But it gives you immense satisfaction to be a part of this long journey through which we can serve the people of our country."

His fellow travellers on this journey, Udhaya Sankar and Amrita, have been with InnoNano as co-founders from the beginning. Talking about Udhaya Sankar, Anshup says, "Whenever we wanted to create new things, it was his eyes which visualized them and his craft which shaped them." Udhaya Sankar is passionate about what he does. "I have learnt that it is the best way to conquer my fear of failure," he says.

About Amrita, Anshup says, "Without her unwavering perseverance and commitment to work, InnoNano couldn't have come this far. In those trying moments, it was her yearning to see a product which kept the work moving." Amrita finds every day an exciting one, as she learns something new which is not written anywhere. "It gives me immense pleasure when I see our products work in the field, and not just on paper or in the lab," says Amrita.

The team has bigger plans still. They are in the process of creating another company, which will develop the same technology for the household consumer market as well as for sale to other countries. This is in partnership with a venture capital firm which has constantly supported the water research programme for the past two years.

They also plan to perfect their antimicrobial unit, which, as they verified through laboratory tests, kills the microbes responsible for a range of illnesses such as hepatitis, encephalitis, diarrhoea and gastroenteritis. "All were cleaned," says Anshup with obvious delight. "All you need is this cartridge. Before you drink the water, just pour it through that cartridge, and leave it for an hour. It'll be free of all microbes."

Further, they are perfecting the filtering unit for fluoride-contaminated water, which affects parts of Tamil Nadu. If all these different units are used together, it would, as Anshup points out, "be a standalone, completely Indian product."

Prof. Pradeep gives me a quick tour of his lab and the state-of-the-art instruments, some of which he has built himself, and then the new DST-funded premises under construction, whose second floor will be the Thematic Unit of Excellence on Water.

He enthusiastically explains the floor plan, no less than 10,000 square feet, with new labs meant for both basic science, and industry-oriented, research. And a conference room. He then effortlessly climbs rusty ladders at the construction site, which look suspiciously unsteady, taking us to the terrace.

Back inside the lab, the forty or so students go about their work, a beehive of activity. Outside the lab, the Buddha smiles contentedly, knowing, perhaps, that the land of his birth is finally awakening from its deep slumber.

Aakash and Beyond

By Aroon Narayanan and Ranjani Srinivasan

Kapil Sibal's pet project and projected as the UPA's technological reach-out to college students, the Aakash tablet was much anticipated when it was first launched in 2011. It was initially conceptualised as the first "Made in India tablet-computer," and an answer to the One Laptop Per Child initiative, but unlike the latter, it is aimed at college students in the cities. But what got everyone talking about it was its USP – costing a jaw-dropping $35 in a market dominated by tablets priced at well above $400. It was also to be a showcase of India's capability in terms of technological know-how, with IIT Bombay and IIT Madras actively involved in the development.

Developed by Datawind and sold as Ubislate 7 in the market, the first version received a lukewarm reception from critics, with most of them being unhappy with the tablet's performance. A resistive display (the type that requires pointed pressure to get working), coupled with an ARM processor running at 366 MHz, the tablet did not make a big dent in the Android market. Aakash 2 on the other hand, marketed as Ubislate 7Ci, surprised everyone with a 1GHz ARM Cortex-A8 processor and a capacitive display, and provided an icing on the cake with the then-latest version of Android OS – the 4.0 Ice Cream Sandwich.

Although Aakash 2 was better received by the tech world, there were still some who were critical in their reviews. Possibly arising out of a different expectation than what it was supposed to meet, these reviews seemed slightly too hard-hitting. So we decided to get our hands on one and see for ourselves what the Aakash 2 tablet has to offer.

At first glance, the tablet looks like any other 7-inch Android tablet – if not for the Ubislate name printed along the top of the frontside, it could actually be mistaken for a Nexus 7.

The back, though, is unmistakable, with three logos printed on it: (developed by) Datawind, Aakash and (powered by) Ubisurfer. It feels sturdy and firm, providing an excellent build quality at its price.

The screen, at an 800 x 480 display resolution, is not top-notch, but it does the job fairly well. Reading PDF files and e-books indoors is a charm, although the screen gets unpleasant in the sun, which is not too great a concern. There have been complaints galore about games not looking too good on this screen, but it is important to remember it was built for educational, and not entertainment, purposes.

What surprises us most is how infrequently the device lags or hangs. Performance issues are expected at such a low price point, but the tablet belies expectations. It works smoothly under moderate application, browsing and reading requirements, and gets sluggish only when running processor-intensive applications. The software is an optimised version of Android 4.0, and works very well for the tablet.

Almost all other key specs are on a par with other tablets being sold at more than double Ubislate 7Ci's Rs. 4000 price-tag. The camera disappoints, but again, that doesn't matter for Aakash. There is a USB slot and a micro SD slot as well. The speakers hold up their own when used for personal listening.

In the end, the bottom-line is this – Aakash is well worth the money even at its market price. If you are a student and have the opportunity to snatch it up at the subsidised price of Rs. 1500, there is absolutely no reason why you shouldn't. The tablet is undoubtedly a success in what it was designed to be – an ultra-affordable educational tablet.

On a quiet Saturday afternoon, Prof. Ashok Jhunjhunwala takes time off to talk to us about the low-cost Aakash 3 tablet project he is at the helm of. Prof. Jhunjhunwala, of the Electrical Engineering department at IIT-M, is well known for his extraordinary work both as a professor and an entrepreneur. He leads the Telecommunications and Networks Group (TeNeT) at IIT-M, which has been working for years to bridge the gap between rural and urban India and has incubated several products that seek to propel the development of rural areas. The Aakash project aims to revolutionize the role of technology in education in India.

Can you tell us more about the project?

The new version of the Aakash tablet is specified as a 7-inch, extremely low-cost device priced at about Rs. 2500. We intend to, in the initial stages, make it available to every college student in the country so that handling technology does not remain only a dream. We shall provide a lot of accompanying features, but the major goal of the project is to emphasise its ability to improve educational standards.

It is not a stand-alone device in the sense that it requires broadband Wi-Fi. So, we are also working on accessibility and network coverage in locations like schools, colleges and hostels. It is also essential to provide multiple public access points like say, a playground, so that on any day, a student has internet access within his or her reach.

But we realize that providing these in itself will not remarkably impact education. We need to gradually make the process of driving education home appealing – instilling a sense of comfort to the user, what you would term user-friendliness.

It is a fact that a lot of these resources (academic content) are already available but our aim is to develop content that is different in that it makes the user comfortable. We would like to introduce the concept of an interactive e-book. That is, instead of users conforming to the rigid structure of the material, we intend to provide plenty of choice so that they choose their mode of learning. For example, instead of having lectures that last an hour or so, we would like to plug in shorter-duration video lectures (15 minutes or so) pertaining to a section right next to it.

Accompanying it would be animation videos or applications and related facts or even a powerpoint presentation to help in quick review. These visual and audio aids would majorly impact understanding and are more inviting than a rigid one-dimensional approach. Tools for evaluation are also included in the form of quizzes. We are trying to incorporate descriptive questions too, wherein submitted answers go through peer review. Additional accessories like a dictionary and a language-translator are also being considered. I would say, the bottomline is that we are looking to provide pedagogy to students who do not have access to it.

Coming to the monetary part of it, the costs are shared. Content cost is largely one-time and can even be overlooked when seen from the perspective of one student. Connectivity cost is also shared by the community and is not a major factor. What matters most is the device cost and we are working to reduce this as much as possible.

On a personal note, what does it mean to you to be helming this project?

When I joined IIT Madras, there were about 25,000 engineering admits in the whole of our country, per year. A large portion of them, in fact, most of them, fell in the middle-class or upper-middle class category and also were largely from urban areas. Those in the lower-economic strata or in rural areas were deprived of these opportunities. But now, the scenario is quite different with huge numbers of engineering (or even college) graduates every year. So, I think we have almost achieved our goal pertaining to quantity. Then, equity is another area in which we have taken huge strides forward. You will agree that it is not uncommon to see one's maid sending her ward to an engineering institute. The fact that more and more people are getting opportunities is certainly laudable. But we also have to recognize that an area where we have failed majorly is quality. You see, the graphs of quantity and equity peaked so quickly that there wasn't enough time to revolutionize teaching and equip teachers better.

IPT (instructional and performance technology) has been conceptualized to serve as an aid in cases of incompetent or inadequate faculty. In many cases, it also helps the teachers improve.
I believe in 5–10 years we should be able to match the levels of quantity, and also equity in quality; and that is what I want.

What kind of services does our institute provide for the project?

Conceptualization is by far the most important of our services. Coming up with the design, that is, defining the architecture and functionality, and then determining the specifications, is our major area of work. For example, energy efficiency in the tablet is a key feature we are working towards. Apart from that, of course, we are working on content generation and there is a lot of effort in this direction.

What has been your biggest challenge during the course of the project?

Since we are trying to create a unique device, too many people are interested in it and there is too much talk about it. The intention to build and launch such a product has been interpreted as a guarantee to be able to deliver it. As a result, there is too much denunciation even when there are minor flaws. I feel the efforts being put in are clouded by the hype created and handling this kind of unnecessary curiosity has been a major challenge. Also, one must acknowledge that having all the elements, and putting them together as a whole, are different things and the latter is a lot more difficult in implementation.

That was on a rather general note. What else do you think was a technical challenge pertaining to this device?

Well, I think it would be the task of balancing performance with cost. It is relatively much easier to develop a device if we are willing for a trade-off on one of the two, but placing both of them at the same level of priority makes the problem non-trivial.

Functional Foods and Problematic Phosphatases

By Aravindabharathi R

As the burgeoning middle class in India adopts an increasingly Westernized lifestyle, with its attendant consumption of food of questionable nutritional value, lifestyle diseases pose an ever-increasing threat to health. Diabetes is perhaps the most recognisable of these diseases. One of the most common complications of type-2 diabetes is the thickening of the walls of the arteries due to fat deposition, a condition known as atherosclerosis. At the Vascular Biology lab on the fourth floor in the Bhupat and Jyoti Mehta School of Biosciences, work is underway to determine the mechanisms linking diabetes and atherosclerosis, and to identify potential cures. The lab is headed by Dr. Madhulika Dixit, who entered the field when she started working on her PhD in molecular biology from IIT Bombay. She is currently an Assistant Professor at IIT Madras, and was recently given the Young Faculty Recognition Award this year on Teacher's Day.

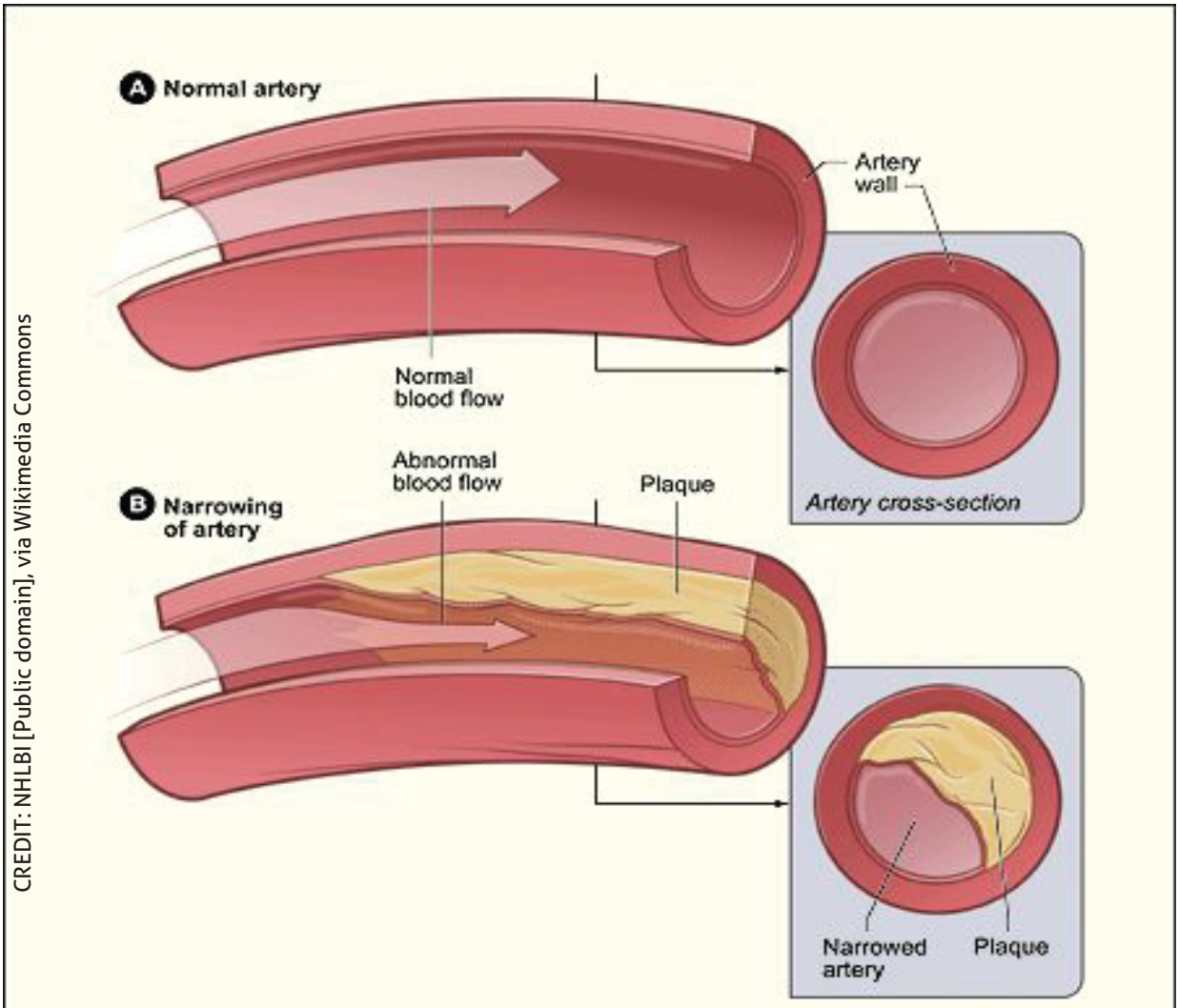
Abhiram is one of the research scholars in the lab. Having taught the microscopy portion of the Cell Biology course to third-year undergraduates in the department and having worked as a TA in their labs, he is probably the best-known research scholar among the undergraduates. He begins by explaining to me the structure of an artery. "There are three types of cells which make up blood vessels: endothelial cells, smooth muscle cells, and endothelial progenitor cells," he says.

PHOTO CREDIT: CDC/Dr. Edwin P. Ewing, Jr., via Wikimedia Commons

Autopsy specimen of aorta opened lengthwise to reveal luminal surface studded with lesions of atherosclerosis.

A single layer of endothelial cells, which belong to the same tissue type that forms the inner linings of the various organs and also our skin, makes up the innermost layer of an artery. This layer is surrounded by smooth muscle cells, which help in regulating blood flow by contracting or dilating the artery when required. Endothelial progenitor cells, as the name implies, give rise to new endothelial cells when the blood vessel has to grow.

Atherosclerosis begins when the endothelial cells start synthesising proteins called Cellular Adhesion Molecules (CAMs) in larger-than-usual amounts. CAMs provide binding spots for white blood cells, which then migrate through the arterial walls into the smooth muscle layer, where they secrete growth factors which affect the muscle cells.



CREDIT: NHLBI [Public domain], via Wikimedia Commons

The illustration shows a normal artery with normal blood flow (figure A) and an artery containing plaque buildup (figure B).

The muscle cells then change into a "synthetic form," named so due to their propensity for synthesising compounds like collagen which reduce the elasticity, and subsequently the integrity, of the endothelial cell layer. They also begin producing new cells, a phenomenon termed as "proliferation," which culminates in the formation of an atherosclerotic plaque, or a fat deposit in the artery.

Work on atherosclerosis in the lab is primarily focused on two areas – determining the pathways by which smooth muscles and progenitor cells are activated to cause atherosclerosis in diabetics, and identifying compounds which can potentially inhibit these pathways.

One of the enzymes the team investigated was a protein called SHP2, which is a part of the insulin-response pathway. It belongs to a class of enzymes known as phosphatases. Organisms can turn their proteins "on" or "off" by adding phosphate groups to, or removing phosphate groups from, certain amino acids on the protein. Enzymes which phosphorylate other proteins are termed kinases, while those which de-phosphorylate are named phosphatases. In general, kinases and phosphatases tend to have very specific protein targets.

In endothelial cells, a protein called eNOS synthesises nitric oxide which, apart from being an important signalling molecule, also inhibits the adhesion of white blood cells onto the arterial walls.

SHP2 regulates eNOS activity and thus plays a direct role in controlling the amount of nitric oxide that is produced. To mimic the conditions of high insulin content in the blood of diabetics, Hemant, a research scholar at the lab, grew human endothelial cells (obtained from umbilical cords and called HUVECs) in an insulin-rich medium for two days. He then performed a test known as an adhesion assay to measure the number of white blood cells which adhere to the HUVECs. In an adhesion assay, HUVECs are first grown on a membrane and then treated with insulin. White blood cells labelled with fluorescent dyes are then added to the membrane. Due to the presence of the CAMs, the white blood cells bind to the HUVECs. After washing off the unbound white blood cells, the bound ones can be counted under a microscope. Hemant found that cells which were chronically exposed to high levels of insulin expressed roughly two-and-a-half times as many CAM molecules as cells grown in normal conditions.

Using a technique called Western Blot, the team then measured the amount of SHP2 produced in insulin-exposed cells, and compared them with normal cells to find that cells exposed to insulin begin producing larger amounts of SHP2 on chronic exposure to insulin. This, in turn, reduces the amount of nitric oxide produced, diminishing the endothelial cells' natural protection against atherosclerosis.

The Vascular Biology group at IIT-M is one of three Indian research centres which are a part of the Indo–European "Funcfood" (short for functional foods) project, which aims to identify compounds with potential medicinal value in treating age-related illnesses, from plants which have been used in traditional herbal medicine.

The lab's work as part of the Funcfood project has been quite fruitful, with the identification of two compounds which inhibit the proliferation of smooth muscles, which results in the formation of atherosclerotic plaques. The first is a compound called isovitexin, extracted from the roots of the Gentiana lutea plant, also called the bitterwort. Due to their bitter taste, the extracts of the root have been historically used in Serbian and Peruvian medicine to make tonics to treat indigestion and gastric infections. Previous research on these roots had suggested that they have beneficial cardiovascular effects, which was why it was selected as a candidate.

To determine whether the root extracts affected the proliferation of muscle cells, Rushendhiran, a research scholar in the lab, cultured smooth muscle cells in a medium rich in the compound PGDF-BB (short for Platelet-Derived Growth Factor BB, one of the growth factors secreted by white blood cells), and found that a large proportion of them had changed from their normal ("quiescent") phase to the synthetic phase. Cells which had been treated with the root extracts, however, did not enter the synthetic phase, showing that the extracts contained compounds which could inhibit the onset of atherosclerosis. He also found that the production of nitric oxide, a compound involved in many intra-cellular signalling pathways, was reduced in cells treated with the extract, hinting at the biochemistry behind the process.

The other compound the lab has identified is ellagic acid, a chemical found in large quantities in raspberries. Using a technique very similar to that used by Rushendhiran, Uma Rani, another researcher in the lab, determined that ellagic acid inhibits the effects of PGDF-BB on smooth muscle cells. Taking it one step further, the team studied the effects of ellagic acid on atherosclerotic rats. To do this, they first injected rats with the compound streptozotocin, which kills off the beta-cells of the pancreas which are responsible for producing insulin, making the rats diabetic. Among these animals, the team found that those which had been fed ellagic acid regularly had thinner layers of fat deposited on their arteries, compared to their untreated counterparts. Analyses of their smooth muscle cells also showed that ellagic acid reduced the expression of compounds called cylins, which cause muscle cell proliferation, and are expressed in large amounts in the cells of diabetics. As both ellagic acid and isovitexin are found in natural sources, they can be easily adapted to therapeutic uses by advising diabetics to include more fruits such as raspberries in their diet, giving us a pleasant way of managing a disease which otherwise would have been the blight on a person's golden years.

Vials on Dial

By Isha Bhallamudi

A few months ago, a group of students and recent graduates of IIT Madras released an Android application and a website called Bloodline that aims to harness the power of technology and mobile networks to save lives, by creating a network of blood donors that could help people in need.

Siddharth Swaminathan, now an alumnus from the mechanical engineering department of the institute, is the co-creator and website developer of Bloodline. When asked about the inspiration behind Bloodline, Siddharth says, "We were faced with the desperate need to find blood donors at the critical hour. Many of us had faced it at different points of time. One of our team members, Sheeba, had to find blood for a relative for an operation. Ashwin, another of my team members, had to go through the same process for his grandmother's cancer treatment. We got together and wondered, why is it that in this world of fast internet and social connectivity, we can't reach out to people? If we can share photos and videos that can be viewed by thousands of people in a few minutes, why can't we do the same for a critical need?"

But many websites give you a huge list of people who have donated blood. Siddharth says, "This is often outdated; the problem with that sort of exhaustive list is that you need to manually contact each and every one of the people on it. You don't want to be doing that when your loved one is in an emergency room or in the operation theatre."

Siddharth explains how Bloodline solves these problems: "Bloodline is not just a website or a mobile application, but a network of people like you and me, who are ready to donate blood in the hour of need. Instead of getting a list, you directly get people who are ready to donate. Bloodline does the work of contacting people for you, and only if they're ready to help do you get their contact details. We solved two problems in one go – privacy and effective communication."

Putting the idea into practice definitely wasn't a smooth ride. The team ran into many issues while developing Bloodline and it took them around seven months to launch it. Siddharth talks about some of these: "The first issue was manpower. It took a while and a lot of looking around to find developers. I built the site mostly by myself. For the app, luckily, we got in touch with Junaid. He did the entire Android app. We deployed the site on a Linux server in the USA over the Python-based web-framework Django. We had our design team, headed by Priyanka, churn out some cool designs."

Other team members include Vasant Sridhar, who manages the business development side of the enterprise; Ashwin Krishnamoorthy, who handles the marketing and everyday operations; Sheeba Rajagopalan, who takes care of the financial side and legal expenses, as well as Arun Vinayak, who also manages business development and marketing.

Siddharth tells us that a critical issue was to get the app and the website to communicate with each other. "This involved significant abstraction in the way the code was handled, including model design, embedding REST frameworks... I started building the site around February 2013, and was close to done by May. The app was developed simultaneously, and then we had to spend a couple of months of all-nighters at Department of Management Studies (we weren't supposed to be there, but blasted LAN cuts!) integrating the two."

What other caveats came up? "Then, we ran into questions of user-interface and workflow. As a user, what would you expect out of the site? What do you want to see when you first get to the page? Should we let you place requests without signing up? Well, we still haven't answered a lot of them, but we'll keep growing and adapting as we do so."

The team's vision for Bloodline is for it to become the single-point solution for blood requirement across the country. "The idea is to establish it as a trustworthy network that you go to and get help from immediately by reaching out to thousands of willing people," says Siddharth.

Their focus is on getting regular blood donors to start using the network. "We're working really hard to get blood banks and other hospitals on board. Often, blood requests are placed via hospitals and not by individuals. The hospitals can also place requests on Bloodline, conduct blood donation drives, just about anything. Our strength is our infrastructure and the power of communication over the Internet."

Siddharth tells us that they are concentrating their efforts on Chennai for the time being. "However, the idea itself is not centric to any location. We will soon be establishing ties in other cities like Bangalore and Mumbai." According to him, the best thing about this solution is its lateral scalability – users can sign up from any part of the nation, yet only the donors in that region will be targeted.

Siddharth is very happy with the kind of response Bloodline has received in such a short amount of time. "We've had more than 870 users signing up, 600 app downloads, and over 700 likes on Facebook so far. We've also been receiving positive feedback from various sources – the Google Play Store, for example. We were cited on *Wired UK* within just two days of launch. *YourStory*, a catalog of Indian startups, ran an article on us. *NextBigWhat* featured us on their feed. *The Times of India* recently published an article on us." Well, you get the drift.

"As I see it, I think we're constantly on the upward incline when it comes to publicity and response. What hit us is the amazing number of sign-ups." By signing up, you don't just get to place requests at the hour of need. It's much more. As Siddharth enumerates, "You also get to donate, help someone, save a life. It's such a response that reminds us of the humanity in every one of us."

Bloodline is completely free. "It always will be," says Siddharth, "We do not like the idea of charging you in your time of critical need. What we want to ensure is that you do not face the cost of a life. We've invested a lot in this, and, as of now, are primarily looking for support in terms of donations."

Bloodline

The team would appreciate contributions from anyone. They'd also like to reach out to alumni and other patrons of the IIT Madras community for the same.

IGCS: A Peek into HSS Research

By Isha Bhallamudi

In an institute renowned for technological and scientific prowess, the Humanities and Social Sciences (HSS) department stands out in having established an integrated course offering a liberal arts education within a patently tech-oriented campus. Over the years, it has been eyed with both cynicism and curiosity by non-Humanities students. However, interest in Humanities work has been increasing in recent years, and activities that had previously been relegated to the "arts people," such as theatre, are now seeing a lot more participation from the institute as a whole.

Founded in 1959, the HSS department at IIT Madras is as old as the institute itself. Back then, its scope was limited to the research work carried out by the professors and the electives offered to B.Tech students. However, it has expanded in a variety of ways between then and now, going on to offer one of the most versatile liberal arts degrees in the country and establishing multiple centres of research that promote interdisciplinary developmental work, these being the Indo–German Centre for Sustainability, the Centre for Comparative EU Studies and the China Studies Centre.

The integrated M.A. program was founded in 2006, and at the time of its inception, offered majors in English, Developmental Studies and Economics. The aim was to offer an extensive liberal arts education within a technology- and research-based environment in order to develop multidisciplinary perspectives. As such, the course program was a first in the country. However, the curriculum was revised in 2011 and the choice of majors was restricted to English and Developmental Studies, while making the latter more economics-intensive. Graduates of this course found themselves in a variety of places – from working in NGOs and the civil service, to penning their own careers in literature or poetry, to pursuing higher studies and settling into research-oriented careers and taking up teaching.

In order to facilitate interdisciplinary research on sustainability, particularly with respect to local developmental issues, the Indo–German Centre for Sustainability (IGCS) was established in 2010 in collaboration with RWTH Aachen University.

The funding for the research was provided by the Indian and the German governments, the former through IIT Madras and the latter through DAAD, under their "A New Passage to India" initiative. DAAD is an organization perhaps best recognized by campus students for facilitating annual summer internships in Germany.

Although the IGCS was actually set up in 2010, the foundation was established in 2008 when the German Federal Minister visited the institute to sign an MoU commemorating the 50th anniversary of a strong Indo–German bilateral relationship. Essentially, the Centre seeks to initiate cooperative work, both theoretical and applied, between Indian and German researchers, to provide courses in areas pertaining to sustainable development and to raise the level of awareness about sustainable approaches to developmental issues.

While our director, Prof. Bhaskar Ramamurthi, is the Indian co-Chair, Prof. Chella Rajan, HoD for the HSS department, is the Indian Centre Coordinator. Their German counterparts are both from RWTH Aachen University. In addition, there are four Area Coordinators from each country managing the four broad research areas.

This research work is most certainly not restricted to the HSS department. In fact, the research threads are divided into four areas – water resources, waste management, land use and rural development, and energy; the focus is on analysing and developing solutions to local developmental issues. The work is interdisciplinary, and as such, involves over thirty professors from several departments across the institute, as well as research students. Each of the four research tracks has an Indian faculty and a German counterpart directing the projects being carried out within it.

The primary objective of the IGCS, is, of course, to promote sustainable development. This is carried out through research, teaching, fellowships, summer and winter schools, conferences and exchange opportunities. Pragmatic research work is of course a primary constituent of all these endeavours.

Within the institute itself, courses with a heavy emphasis on sustainable development are offered both as core courses to HSS students, as well as free electives for B. Tech students, such as the course titled Environment and Society. This is a core HSS course that involves intensive reading and analysis centred on contemporary environmental issues.

Let us look at the exchange opportunities provided to faculty. Both long-term and short-term visiting professorships are open to faculty from certain German universities. Meanwhile, fellowships funded by DAAD are provided to a selected number of Indian and German graduate as well as postgraduate students. Interestingly, the fellowships can also be availed by non-IIT Madras students who wish to work on sustainable development initiatives either here or in German universities.

The annual summer and winter schools organized by the IGCS, held alternately at Chennai and Berlin, offer a chance for German and Indian students to work together on local developmental issues, facilitating intercultural as well as interdisciplinary research. The participation is limited to ten Indian and German students each, either graduate or postgraduate, who are selected very carefully by an expert panel on the basis of their research potential. The schools train the scholars on different kinds of environmental issues and involve projects carried out in local areas based on sustainable solutions to these issues, which fall under the ambit of water resources, land and rural development, waste management, or energy.

During the course of these schools, over a time period of around two weeks, research students are exposed to seminars and lectures, and taken on field trips to collect data. They are then expected to prepare project reports and present their findings. For instance, one of the projects carried out in the winter school involved calculating the carbon footprint of the IIT Madras campus and suggesting ways to reduce it, although they concluded that this footprint was much lower than the national average, probably due to the emphasis given to sustainable living by campus residents.

The faculty at IIT Madras, across departments, including visiting faculty, are actively involved with research within the IGCS. Part of this research is funded by the Department of Science and Technology (DST) under the Government of India. One of the research requirements is that "technical, scientific and engineering expertise should be inextricably linked with expertise within the fields of the humanities and social sciences." Principal research areas which have been designated include organic farming, plantation economy and rural electrification. Further, specific research topics are suggested within the ambits of water, land, energy, and waste management, these being crucial areas of research where development and new methodologies would be of direct benefit to many local communities, not just in Chennai, but across the country as well.

Under the program "Strategic Knowledge Mission on Climate Change," the DST has funded a series of projects aimed to encourage collaborative research. All these projects fit within what are termed as the eight key sustainability challenges, some of which are ensuring air quality, improving public sanitation and sustaining urban water bodies. The Adyar River Project, falling under the last category, is one of the more significant research projects that have been undertaken in this regard. It seeks to analyse the environmental and social issues affecting the river, such as heavy industrial pollution, silt and lack of adequate sanitation facilities in the communities surrounding the river. By proposing sustainable solutions and policy reforms, it aims to have a long-term impact on the ecological and social aspects of the region.

Since its inception, the IGCS has been active in fostering research centred on sustainable solutions to developmental issues, especially by encouraging local projects. However, the visibility of this work within the campus itself is quite low, even among the HSS students. One contributing factor might be that the level of undergraduate involvement in IGCS initiatives is mostly limited to the courses taken by students within the institute. It would perhaps be fruitful for undergraduate students from both the HSS and other departments to be actively involved with the local projects, where possible.

While conferences organized by the IGCS, such as the National Climate Change Conference, held quite recently, in October, invite student volunteers, the outreach is quite restricted and not too many students get to hear of these opportunities, which is a pity because these conferences, seminars and workshops, not to mention the projects, have a lot to offer.

Among the several conferences organized in the institute this past semester was the 4th National Climate Change Conference, on October 26th and 27th. It was held under the banner of the Indian Climate Research Network (IRCN), which comprises four institutes – the Indo-German Centre for Sustainability (IGCS), the Indian Institute of Science, IIT Delhi and the Centre for Science and Environment (CSE) Delhi.

The objective was to develop the capacity and influence of climate change research in India, which is not as focused and intensive as climate change research abroad. This was achieved mainly by bringing together a network of diligent researchers and conducting presentations, seminars and panel discussions. The focus of their work was to be on the science and impact of climate change, climate change mitigation, adaptation, disaster risk reduction and renewable energy. There was an emphasis on independent research and among the participants were students, faculty and civil organizations.

All the events held during the conference were in spirit with the basic aim of creating an arena where Indian researchers on climate could come together and deepen their sense of community.

The aim was to foster an integrated network of people across the country working on immediate climate change issues relevant to India, particularly in the matters of adaptation, mitigation and risk reduction, while emphasizing the importance of alternate energy resources. Because the dangers of climate change are very real, such research is of the highest relevance.

There are two other centres within the HSS department – the Centre for Comparative EU Studies (CCEUS), in partnership with Sussex University, England and established in 2010, and the China Studies Centre. The former is one of four such centres set up in India through research grants provided by the EU. Research domains in the CCEUS are delineated into Globalization and International Relations, and Democracy and Developmental Studies, with a set of research tracks specified within these.

Prof. Sudhir Chella Rajan at the National Climate Change Conference

The idea is, evidently, to look at political development in democracies and its influence on global power structures with respect to South Asia and the EU. Since its inception, multiple conferences, seminars and workshops have been organized to promote such research work.

However, it must be said that of the three, the China Studies Centre is certainly the most well-recognized by students in the institute, the other two centres having low visibility among undergraduate students in the campus. It was established in 2011 to address the increasing need to study the role of China in contemporary global politics. How does it accomplish this? For one, it seeks to familiarize students to the language and offer them a chance to learn more about the global political scenario in this context, by offering introductory courses as electives. There is an emphasis on bilateral research and exchange opportunities, with visiting faculty positions being offered to Chinese scholars, and doctoral and post-doctoral fellowships being open to students for work in this research field.

Nano Sensors for Bacteria

By Sachin Nayak and Aroon Narayanan

Nanoelectromechanical systems (NEMS), as the name implies, are electrical and mechanical devices whose sizes are of the order of one nanometre (a billionth of a metre). They are the successors of the micro-scale devices called MEMS, which various groups at IIT-M have worked on. NEMS find applications in the detection of adulterants in food, of bacterial antigens and thus the bacteria themselves, of hazardous gases, and in communication using frequencies in the gigahertz-range. One of the most promising applications to come out of IIT-M is a "diving board" sensor for detecting bacteria.

Before a diver jumps off a diving board, he or she usually makes a few small jumps, causing the springboard to move up and down. As soon as the diver jumps off it, it begins vibrating at a much higher frequency. To an engineer, a diving board is a type of structure called a cantilever. Cantilevers are beams that are attached to a support only at one end. They have been around for a long time, and are quite ubiquitous today. They are very common in construction, and can be seen in towers, bridges, and roofs. The wings of an aircraft, being anchored to the body of the plane at just one end, are also cantilevers.

When shrunk to the nano-scale, cantilevers can perform functions which are, initially, quite baffling. For over a decade now, nano-scale silicon cantilevers have been used as sensors. These sensors are so small, that ten of them stacked side-by-side would appear about as big as a grain of dust.

To understand how cantilevers can be used as sensors, we must go back to the example of the diving board. A diving board, or any cantilever for that matter, vibrates with a particular frequency called its resonant frequency. This depends on the mass on the cantilever. When the diver is standing on the board, there is a constant downward force on the cantilever (the diver's weight) "damping" its vibrations. When the diver jumps off it, the damping force is removed, and the cantilever begins vibrating at a higher frequency.

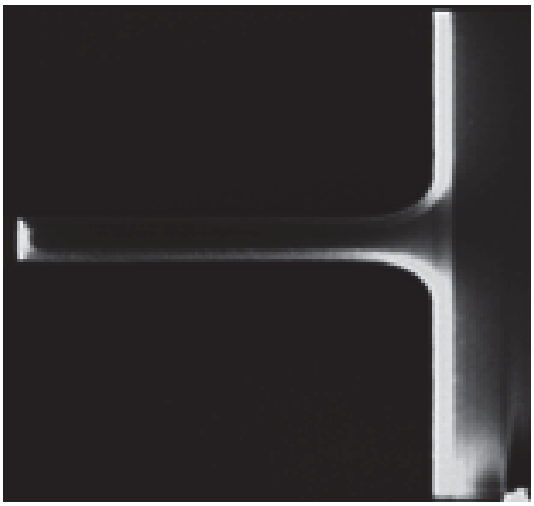


IMAGE CREDIT: Prof. Enakshi Bhattacharya

A polysilicon cantilever.

To exploit this property of cantilevers for use in sensors, the following apparatus is used: A laser source is set up over the cantilever and the light reflected by the free end of the cantilever is sensed by a detector. A piezoelectric vibrator, similar to quartz crystals used in wristwatches, sits on the other end of the cantilever. The cantilever is vibrated at different frequencies and the reflected beam gives the highest intensity when the cantilever vibrates at its resonant frequency.

By a process called functionalization, several layers of chemicals are deposited on the cantilever to make it sensitive to a specific chemical, antigen, compound, or even a whole virus. Now, only that specific particle can bind to it. The resonant frequency of a cantilever is first found without any weight on it. Then, the cantilever array – a single cantilever is never used – is placed in a buffer solution with the sample (blood serum or urine) dissolved in it. If the particle to which the cantilever is functionalized is present in the solution, it binds to the cantilever. Measuring the difference in frequencies of the mass-free versus the mass-loaded vibrations allows researchers to tell whether the specific particle is present in the solution or not.

This method helps in detecting the presence of a bacteria or a virus in a sample in much lesser time than conventional methods.

To detect bacteria, the cantilevers are coated with antibodies which target specific proteins on the surfaces of the bacterial cells, called antigens. Since each bacterium produces many antigens, this method is more sensitive than looking for the bacteria themselves, and can show the presence of amounts of antigens or chemicals that cannot be detected by conventional methods.

The MEMS Centre of IIT Madras has been successful in obtaining urine profiles using this method. Now, their focus of research in the area of biomolecular detection is to detect antigens present in the blood serum or urine samples to detect disease-causing agents.

Gaurav Kathel, an MS student there, says, "By conventional methods, testing the blood of a person suspected to be infected with malaria takes 4–5 hours. However, by this method, the process takes only 20 minutes and the presence of even a single malaria-causing protozoan can be detected."

Even though cantilever sensor technology is a hot topic of research in the field of NEMS, there is still huge scope for further research. Arrays of these sensors could be used to analyse blood for the presence of viruses, or water for the presence of pollutants. The extremely high resolution of the devices would allow for more accurate, and earlier, warnings than were ever possible before.

From the Ruins

By Arjun Bhagoji

What happens when technology meets heritage? Good things, it would seem, as evidenced by the Indian Digital Heritage project of the Department of Science and Technology (DST). The project aims to create virtual 3D interactive walkthroughs of ancient Indian monuments starting with the ruins at Hampi, a UNESCO World Heritage Site. Various aspects of the projects are being dealt with by academic and industrial research groups around the country, including one here at IIT Madras.

The group at IIT-M is headed by Professor A.N. Rajagopalan of the Department of Electrical Engineering and they are working on creating virtual reconstructions of damaged objects, such as statues, in the ruins. Using techniques from computer vision, they are attempting to make these damaged statues whole again to ensure a pleasant walkthrough for the user, allowing him or her to appreciate these magnificent buildings as they were in their heyday, unblemished by the ravages of time. The challenge lies in accurately reconstructing parts of the monument so that they look authentic and fit in perfectly with the remaining, undamaged parts.

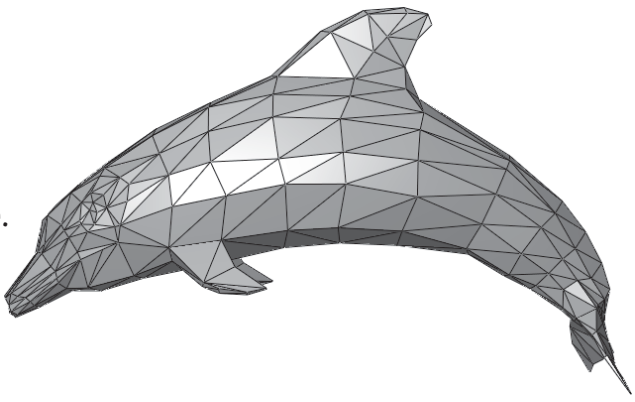
Pratyush Sahay, a former graduate student at IIT-M and a part of this group explains, "There are three main steps in the process of virtual reconstruction. First, a 3D model of the damaged object has to be created. Then, the missing or damaged portion has to be accurately marked on the model. Finally, the missing portion has to be filled in correctly, with say, a nose appearing where a nose ought to be, and not a head!"

The main contribution of the group at IIT-M is in the final step of the process. However, even the first step was prohibitively expensive till a few years back when a lot of progress was made in the field of 3D reconstruction. Earlier, one had to use expensive laser range scanners in order to create digital models of objects. These scanners would bounce laser beams off an object and use the pattern of the reflected rays to determine its shape.

Now, however, it can be done using an off-the-shelf camera. Images of a 3D object are taken from various points of view and the technique of triangulation is used to determine the location of a point on the object in space. Rays are projected back from pixels in the image corresponding to the surface of the object and the meeting points of these rays give us the location of a point on the surface in 3D.

One might ask, since there may be millions of pixels in an image, how do we know which ones correspond to the contours of the object and hence, whose location should be determined? One could manually mark the points but the sheer number of pixels in a high-definition image makes this an extremely tedious task. To overcome this problem, a method known as corner point detection is used. This approach allows one to determine pixels corresponding to the same point on the object across the set of images by finding the maxima in the gradient domain map of the image. In the simplest version of this method, the intensity gradient at a pixel is found by taking the difference in the intensity values of the adjoining pixels along both the x- and y-axes. Recent methods use a more complex methodology to get a better feature vector for a cluster of pixels, as opposed to just one pixel, which aids corner point detection.

Typically, an image with a million pixels will have a few thousand corner points which are triangulated to create what is known as the point cloud of the object. This is just a collection of points floating in space giving you a rough idea of the shape of the object. Taking a step further towards a more concrete visualization, a mesh is created from the point cloud by methods such as Delaunay triangulation, where points are connected by triangles satisfying certain properties, giving a tessellation of sorts of the object's surface (see image below).



CREDIT: Chrschn, via Wikimedia Commons

A triangular mesh representing a dolphin.

Once the mesh has been created, the question naturally arises, how do we know where the damaged portions – let's call them "holes" from now on, for simplicity – are? Marking the holes on the reconstructed 3D object may require the use of pricey, complicated software so the marking is done on the images themselves. Then, using the back-projection method explained before, the damaged region on the 3D model can be obtained by these markings.

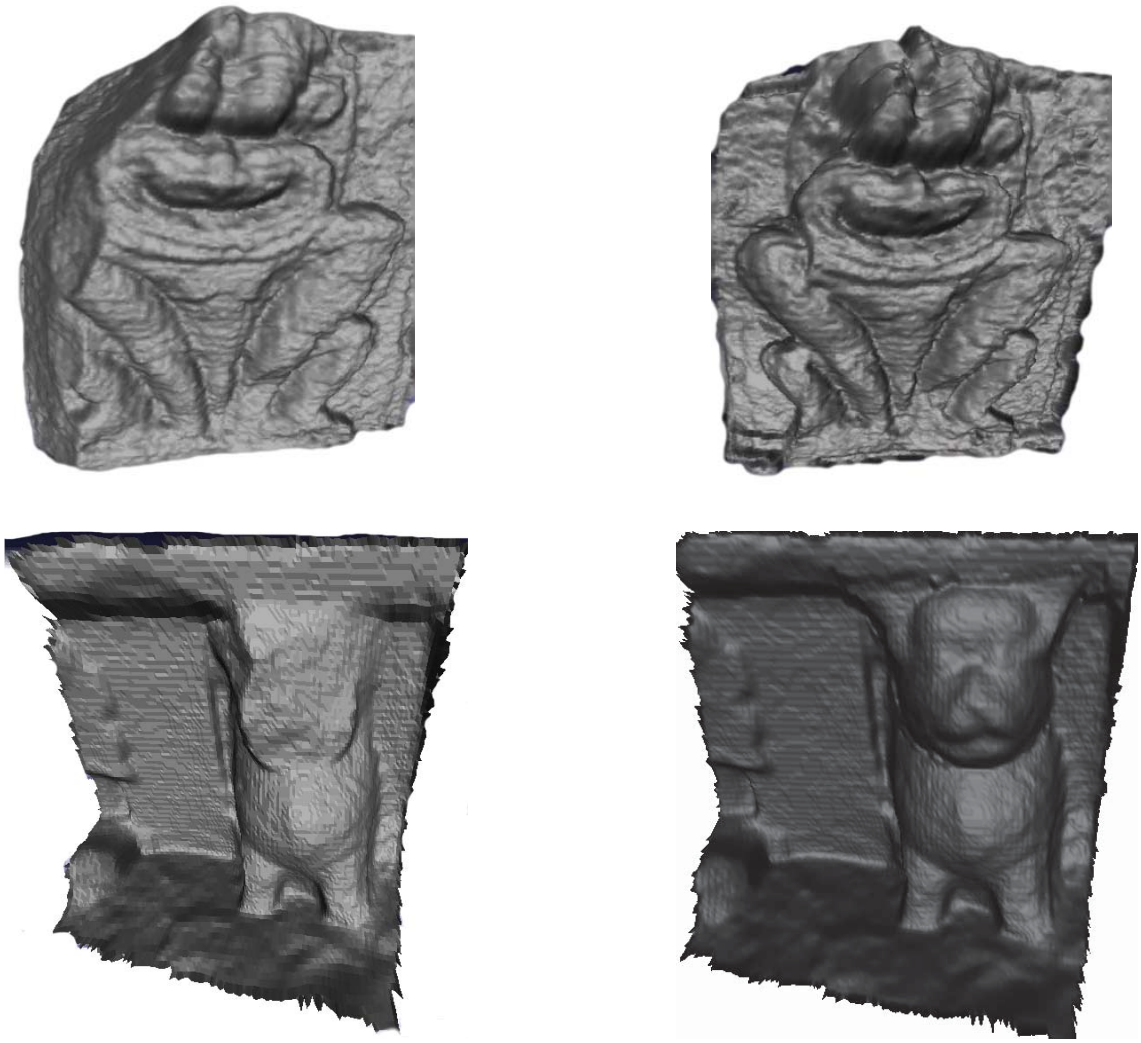
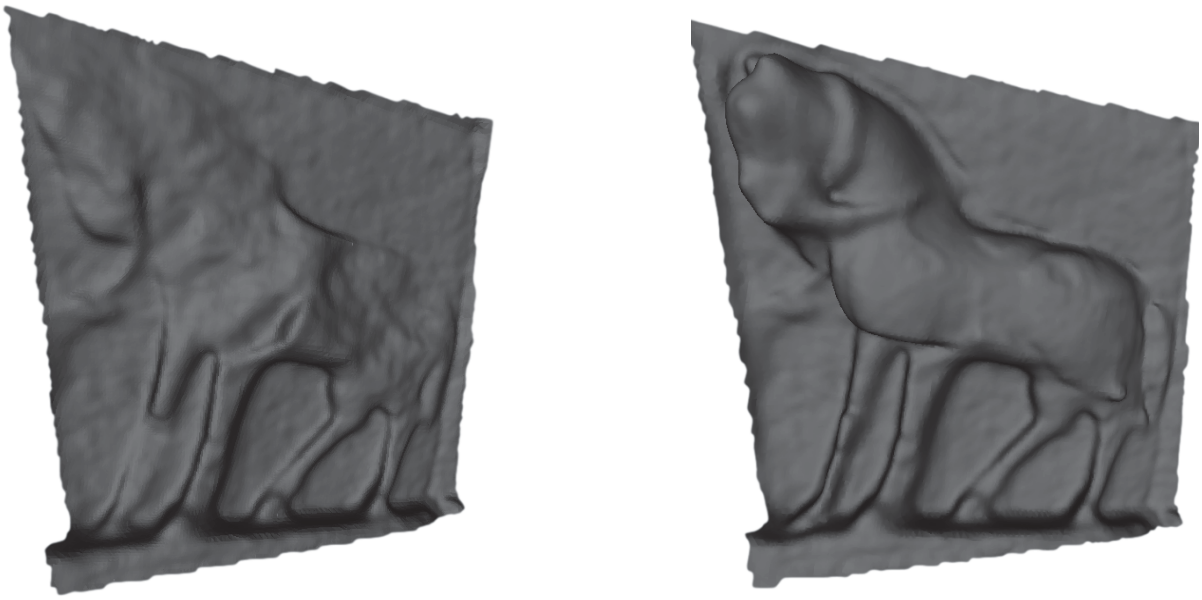


IMAGE CREDITS: Prof. A. N. Rajagopalan and Pratyush Sahay

A stone carving of Narasimha from Hampi (top left) and its reconstruction (top right). A lion face from Mahabalipuram (bottom left) and its reconstruction (bottom right).

Hole-filling in digital representations of objects has been done before, most notably in a similar context by Marc Levoy's group at Stanford, where they corrected small imperfections in the 3D scan of Michelangelo's David. The key difference, however, is that they filled in small areas which were missing only on the 3D model created due to issues with the laser scanning process, but which were actually present on the statue itself. The methodology used by Levoy's group works for small missing regions and not for a hole as large as a nose or a face, as it is based on simple surface geometry extension, that is, interpolation. Now, filling in a large hole which contained a feature with a distinctive shape, without any prior information on what the feature was, is infeasible. For example, imagine a missing nose. Trying to reconstruct it by simply interpolating from the boundaries of the hole is likely to give you an indistinct mess which looks nothing like a nose.

To overcome this, a database of structurally similar models is used and points from these



A figure of a horse from Hampi (left) and its reconstruction (right).

IMAGE CREDIT: Prof. A. N. Rajagopalan and Pratyush

existing models are put in as estimates in the hole of the incomplete model.

Large databases exist for features such as faces and bodies, which contain information about the orientation and the size of the models in them, so they can be appropriately rotated and scaled to match the one to be reconstructed. Without this information, these models cannot be used since they may not be similar to the desired model. This presents a problem while trying to reconstruct objects at heritage sites, since large databases with the necessary information do not exist.

So, models are taken from statues at the same site or elsewhere, the point cloud of which is transformed with respect to the damaged model in order to obtain information about their relative orientation and sizes, and, finally, the estimation is performed as before. The transformation is done using robust point cloud registration techniques.

Once the point cloud with the estimates for the hole is ready, a technique known as tensor voting is used to fill in the hole. The local geometry at each estimated point is determined by collecting "votes" from known, undamaged regions of the object, wherein a vote is a communication of structural preference. The estimate point which receives the highest number of votes is now included as part of the undamaged region and the process is repeated again. This continues until the entire hole has been filled up.

Dr. Rajagopalan's group used the methodology described above to reconstruct damaged statues at Hampi and Mahabalipuram, with stunning results.

The group is currently working on using similar techniques to estimate the intensity pattern of the damaged regions as well. A beautiful example of how beneficial technology can be even for art and history, one hopes to see more work like this from research centres throughout the country.

The Need for SPEED

By Ananth Yalamarthy

In the midst of an experiment in early 1908, the German physicist Hans Geiger was perplexed: his new device that was supposed to count charged particles from a radioactive source, was doing so, even in the absence of a source. Where were these particles coming from? When scientists launched a balloon with Hans' device into space a few years later, they observed the particle count steadily increasing with altitude, leading them to conclude that these particles, mysteriously enough, came from outer space. In the early 1950s, the flurry of excitement surrounding this discovery was still alive, and inspired the young physicist Van Allen to launch Geiger counters on whatever means of ascending from the ground he could find.

What, you might ask, is keeping the charged particles trapped within the doughnut? The answer, it turns out, has to do with Earth's magnetic field lines, which too, are doughnut shaped.

We've all learnt in high school that a moving charged particle, when injected at an angle along a set of parallel magnetic field lines, executes a circular motion around the field lines, while at the same time moving along it. The charged particles in the Van Allen belts undergo a similar motion, save for two important differences: the field lines are curved and their density is not the same – it's much higher at the Earth's magnetic poles.

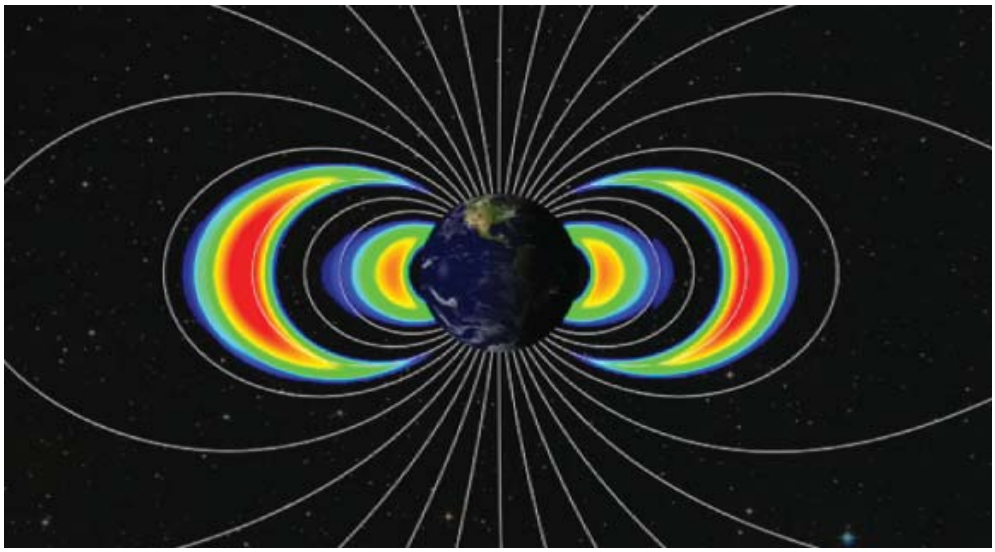


IMAGE CREDIT: NASA
http://ipy.gsfc.nasa.gov/vis/a010000/a011200/a011212/

This visualization, created using actual data from the Relativistic Electron-Proton Telescopes (REPT) on NASA's Van Allen Probes, shows the doughnut shaped inner and outer Van Allen belts, filled with charged particles.

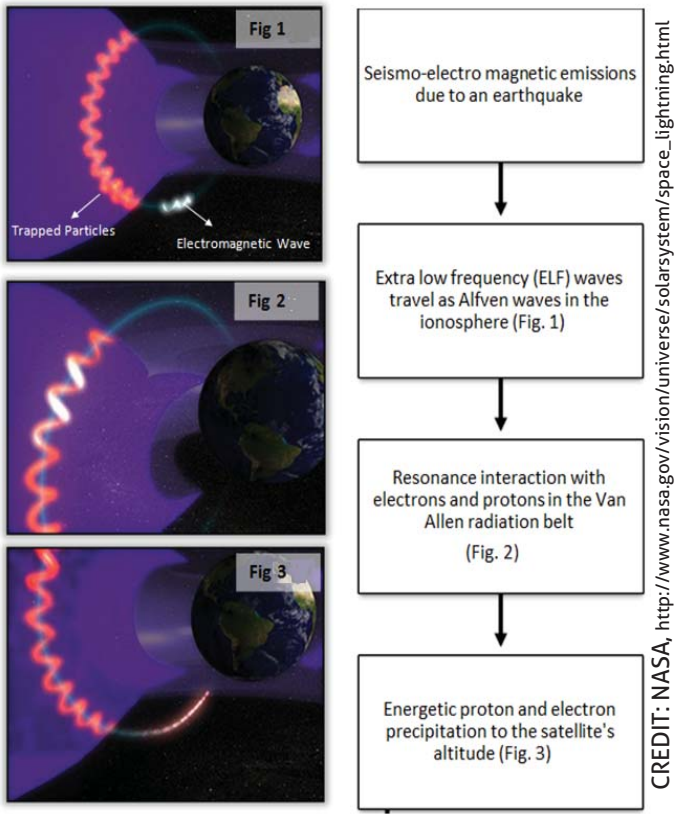
When the United States launched their first satellite in 1958, the Explorer I, it carried a Geiger counter built by Dr. Van Allen as its payload, which is the main functional unit of a satellite. As Explorer I looped the earth, live count measurements showed an unexpected pattern: The counts suddenly went high in certain regions of space, leading to the first major discovery of the infant space era, the aptly named "Van Allen" radiation belts. Encircling the earth in the form of a giant doughnut replete with protons and electrons, the Van Allen belts are the subject of study of several space missions today.

When a charged particle in the belt moves towards the poles, it feels a stronger magnetic field, which makes it reverse it direction and move towards the other pole, where it repeats this behavior. This endless loop of particles bouncing back and forth is what keeps these charged particles trapped.

The behaviour, as you might have guessed, isn't this simple. There are particles which free themselves from this trap and also new particles getting trapped all the time, due to various phenomena.

A good example of particles escaping the Van Allen belts is the majestic aurora occasionally seen in the night sky near the polar regions. As the principal mission of the IIT Madras Student Satellite Project (IITMSAT), we are interested in one particular cause of the escape: the interaction of charged particles with electromagnetic (EM) waves produced on the earth.

EM waves are produced due to a variety of phenomena. Of particular interest to us is a particular type of low-frequency wave thought to be produced in the days leading to an earthquake at its epicenter. It turns out that these waves match the frequency of gyration (rotation of the charged particle around the field line) of the charged particles in the Van Allen belts, providing a favourable condition for the energy of the wave to be transferred to the particle. When this occurs, the particle now has enough energy to push against the repulsive magnetic field at the poles, and drops out of the Van Allen belts into low Earth orbits – orbits at an altitude of 500–800 km from the Earth's surface – where it can be detected. All of this occurs in a very small instant of time after an EM wave is produced, and thus, what we really see is a sudden "burst" of particles in space. IITMSAT's payload is built to detect precisely this burst, allowing us to predict expected seismic activity at a particular location on the ground.



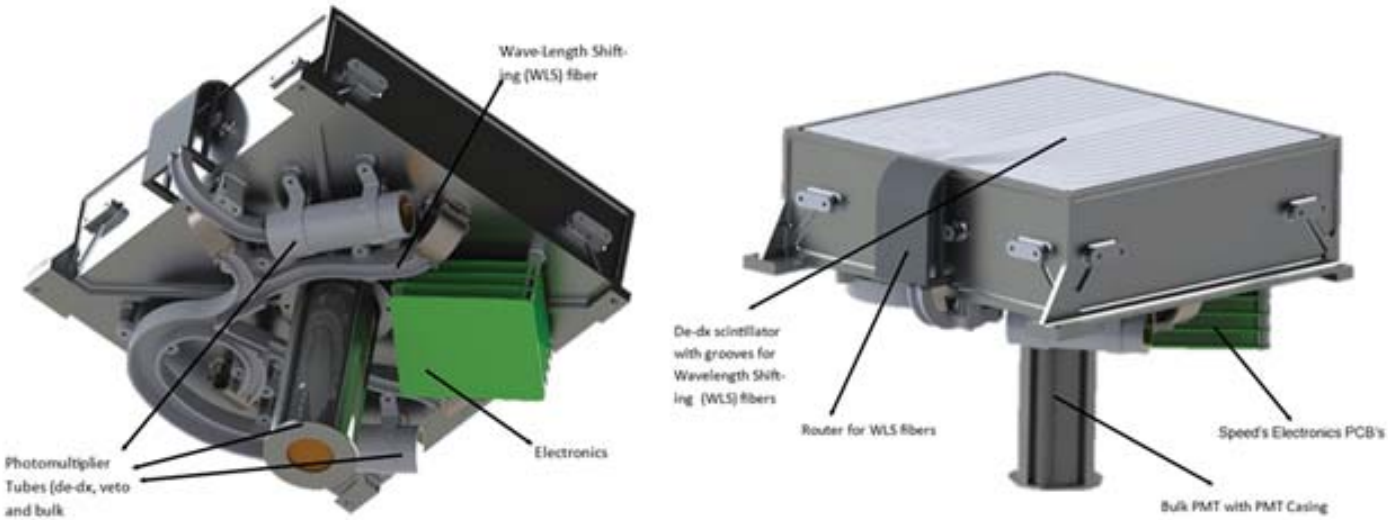
This sequence of images illustrates how an electromagnetic wave can cause a particle in the Van Allen belts to escape, so that it can be detected in the low Earth orbits.

To better understand this phenomenon, we built a computer model last year to simulate the interaction of an EM wave with the Van Allen belts, and to study the nature of the charged particles that are precipitated. Thus, we know how much precipitation to expect in the low Earth orbits and the energy of the charged particles that IITMSAT's payload will see when in orbit. The Space Based Proton Electron Energy Detector (SPEED), IITMSAT's payload, which has been in development for nearly three years now, is steadily reaching completion.

In order to detect charged particles, SPEED uses materials known as scintillators, which fluoresce when a charged particle strikes them. A charged particle that travels through a scintillator knocks off electrons from its atoms, leaving a void. When electrons from a higher energy state drop down to replace the knocked off electrons, they lose energy in the form of blue light.

In SPEED, this blue light enters "wavelength shifting" (WLS) fibers, which cover the scintillator surface. The WLS fibers convert this blue light into green light, which is then transported along the length of the fiber to devices known as Photomultiplier Tubes (PMTs). The PMTs then convert the light into an electrical signal which is amplified and fed into an electronics system that processes the signal and returns information on the energy and the type of the incident particle.

SPEED's development over the last three years has been an interesting journey, with the design undergoing several critical modifications as our understanding of the phenomenon evolved over time. After several iterations, we now have a complete structural prototype of SPEED that is designed to meet the strict Polar Satellite Launch Vehicle (PSLV) conditions. This allows us to put together our scintillator modules into one compact package and finally test them all at once.



These images show the bottom view (left) and the top view (right) of the SPEED payload. Only the top scintillator is visible in the top view image. CREDIT: The IIT Madras Student Satellite Project.

The IIT Madras Space Center is currently being built at the Electrical Engineering Department, which will house several test equipment, in addition to a clean room that will help accelerate our experiments in the next few months. With parallel developments on developing the instruments and understanding the phenomenon, we are making headway in building a satellite whose scientific mission, if successful, is bound to have a definitive impact on the way we understand the Van Allen belts' mysterious phenomena.

A BRIEF HISTORY

The IITMSAT Project was created by a group of enthusiastic first-year undergraduate students in 2009, with the aim of launching a satellite with a socially relevant scientific mission. The initial funding for IITMSAT was in the form of an "innovative student's project" grant, provided by the Industrial Consultancy and Sponsored Research (ICSR) unit of IIT Madras. For about a year, the team experimented with the feasibility of several possible payloads that could be flown on IITMSAT, and developed an organizational structure for the satellite by dividing it into seven subsystems: the communication subsystem, the electrical power subsystem, the payload, the attitude determination and control subsystem, to name a few.

The idea of flying a high-energy-particle-detector was finalized after a discussion with scientists at ISRO's satellite center in 2010, and this eventually led to the SPEED payload that stands today. As of now, we have a group of about 25 dedicated undergraduates working on various aspects of SPEED and the rest of the satellite, while certain specific units have been converted into Masters projects with the aid of faculty members.

Over the years, the IITMSAT has greatly benefited from collaboration with several institutes in India and abroad. SPEED's initial development was carried out in the form of internships at ISRO's satellite center, Tata Institute of Fundamental Research (TIFR), Mumbai and Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram. In order to develop certain units of the satellite's subsystems, our team members worked at York University, Canada and EPFL, Switzerland, which have prior experience in nano-satellite development. In this regard, we have also received recognition and useful feedback at several conferences, the most recent of which was the 5th Japanese Nano-satellite Symposium at Tokyo, in November 2013.

The funding for IITMSAT comes from different sources, of which our Institute and alumni have been the major ones. A significant portion of these funds is being used to construct the IIT Madras Space Center. We aim to complete the project in 2015.

CREDIT: The IIT Madras Student Satellite Project

FURTHER INFORMATION:

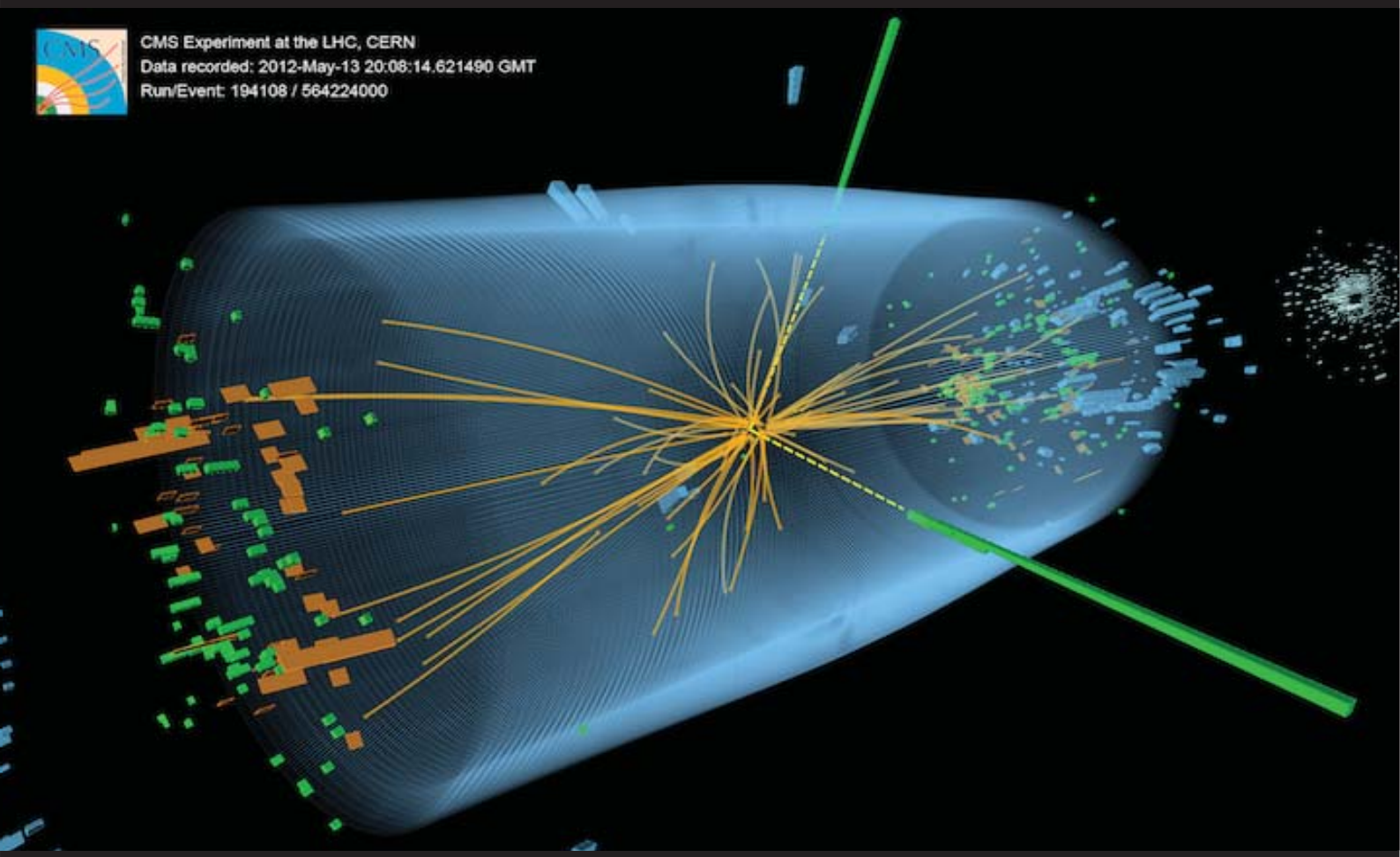
IITMSAT's official website: www.iitmsat.iitm.ac.in

A non-technical overview of the IITMSAT project, "Unveiling the Aurora: IITMSAT," is available at http://t5e.iitm.ac.in/2013/08/unveiling-the-aurora-iitmsat/.

For further information, please contact Nithin Sivadas at astronithin@gmail.com.

The Elusive Goddamn Particle

By Vishakh Hegde and Nithyanand Rao



Candidate Higgs boson events from collisions between protons in the LHC. This event in the CMS experiment shows a decay into two photons (dashed yellow lines and green towers). CREDIT: CMS © CERN

A hundred meters under the Franco–Swiss border, two beams of a hundred trillion protons each, travelling in opposite directions in circles of 27-kilometre circumference at a pace that sees them complete over 11,000 circuits in a single second, and controlled by superconducting magnets maintained at two degrees above absolute zero, smash into each other. Over half-a-billion collisions per second. From the petabytes of data, of over 1,000 trillion such collisions spread over two years, emerged signatures of a long-sought elusive particle. This particle, the avatar of an all-pervading field, reveals its presence only through its progeny. It is the manifestation of a mechanism that gives elementary particles their mass, and was the one missing brick in the Standard Model, the organizing framework for the known elementary particles.

The Large Hadron Collider (LHC) at CERN, like other particle accelerators is, in essence, a powerful microscope. By Einstein's mass–energy equivalence relation, new particles arise from the energy liberated by the particle collisions. The higher the energy of the beams, the heavier the new particles created. These ephemeral particles then decay to more stable ones, and an analysis of these decay products enables particle physicists to reconstruct the sequence of events and decipher its governing laws.

What makes the LHC different from other particle accelerators is the unprecedented energy with which the colliding beams smash into each other: 4 TeV each for a combined 8 TeV, with plans to ramp this up to 7 TeV each. Here, TeV stands for tera, or a trillion, electron volts. An electron volt

is the energy gained by an electron accelerated through a potential difference of one volt. It is a convenient unit of energy in particle physics because, in absolute terms, the energies involved are very small. With such energies, physicists are now able to probe matter at scales of 10–18 metres.

Since J. J. Thomson discovered the first fundamental particle, the electron, in 1897 through his experiments with cathode ray tubes, this has been the modus operandi of particle physics – smash accelerated particles into stationary targets or into each other. As physicists kept increasing the energy of the colliding particles, they discovered a bewildering zoo. An organizing principle was required, a framework which would bring order to the menagerie of seemingly elementary particles. That framework is the Standard Model.

All the matter we see around us is made up of just three particles: protons, neutrons and electrons, of which only the last is a truly elementary, indivisible particle. Protons and neutrons are made up of quarks, which come in six varieties. However, only two of them, called up and down quarks, suffice to make up protons and neutrons. The quarks, along with the electron and the ghostly neutrino, are part of a family of particles called fermions.

The infinitely rich variety of physical phenomena in the universe can be explained by just four fundamental interactions, or forces. Gravity, the most familiar one, is so weak that the entire mass of the Earth pulling down on you isn't enough to keep you grounded. It is, however, a long-range force: the Sun, for instance, exerts its force across 150 million kilometres of space to keep the Earth in its orbit. Gravity, first theorised by Isaac Newton, was also the first instance of what has become the over-arching goal of theoretical physics: unification. Newton unified the terrestrial and the celestial, when he realized that the same force that pulls apples to the ground also keeps the Moon in its orbit around the Earth.

Electricity and magnetism were believed to be related but distinct phenomena, until James Clerk Maxwell unified them with his four equations. This threw up a surprising prediction: light was a wave, thus unifying optics with electromagnetism. But what was waving?

This brings us to a second great theme in theoretical physics – the concept of a field. First proposed by Michael Faraday, a field can be thought of as a set of numbers at every point in space, that represent the strength and the direction of the force a particle kept at that point would feel. There are many kinds of fields: for light, what was waving was the electromagnetic field. Gravity had to wait for Einstein for its own field theory, the general theory of relativity.

The two other fundamental forces are less familiar, confined as they are to the atomic nucleus. What enables the nucleus to exist despite the repulsion between its protons is the short-range strong nuclear force. Neutrons too, interact with each other and the protons through this force. The strong force between nucleons, however, actually comes from the interaction between their constituent quarks. This brings us to another key idea: force-carrying particles. Each fundamental interaction is mediated by particles which are called bosons. These are the quanta, a sort of unit, of their corresponding fields. The quantum of the electromagnetic field is the familiar photon, which is massless. For the strong force between quarks, the force carriers are gluons, while for gravity, the hypothesized force carrier is the graviton.

The fourth fundamental force in nature is the weak nuclear force, also a short-range force. It is responsible for negative beta decay, in which a neutron becomes a proton with the emission of an electron and an antineutrino. It is also essential for the nuclear reactions in the centres of stars like the Sun, where hydrogen is converted into helium. The force-carrying particles of the weak force are the W +, W– and Z0 bosons. In addition to carrying the force, their exchange changes the character of the particles that swap them.

There is a crucial difference, however, between the force carriers of the three other forces and that of the weak force. The photon, the gluon and the graviton are all massless, while the W and Z bosons are heavy, with masses about 100 times that of a proton.

During the 1960s, Sheldon Lee Glashow, Abdus Salam, and Steven Weinberg independently found a way to unify the weak and electromagnetic forces in one mathematical formalism, the electroweak interaction.

The two forces were now on an equal footing – a symmetry. The difference in masses of the messenger particles, and hence the strength and range of the two forces, however, meant that this symmetry was "broken" by some mechanism that gives mass to the particles exchanged in weak interactions but not to the photons exchanged in electromagnetic interactions. This mechanism, the Higgs field which permeates all space, and whose manifestation is the Higgs boson, was proposed almost 50 years ago by three groups of physicists: Robert Brout and Francois Englert; Peter Higgs; and Gerald Guralnik, Carl Hagen and Tom Kibble. By interacting with this field, the elementary particles acquire their masses. Later, the strong force was incorporated into the electroweak theory, resulting in what physicists call the Standard Model.

We spoke to Prof. James Libby of the Physics department of IIT Madras, who is an experimental particle physicist. Prof. Libby has been involved with various experiments at CERN. "It goes back to when I was a PhD student. I worked for the predecessor of LHC, the Large Electron-Positron (LEP) Collider, and I was there in the late 90's. That was all coming to an end because the LHC was due to start running in 2005. The main thing the LEP was designed to do, was to measure the parameters of the Z boson very carefully, one of which is its mass," he recalls. "Electroweak unification was, by this time, very well established because the previous experiments at CERN had obtained signatures of the W and the Z bosons."

Symmetry has been one of the great themes in theoretical physics in the last century. If the symmetry inherent in the Standard Model is not broken, all particles in the world would have been massless, just like the photon. But all elementary particles, except photons and gluons, are known to carry a rest mass.

"That is what the Higgs boson does. It breaks the symmetry and gives mass to these particles, through a process called spontaneous symmetry breaking," explains Prof. Libby. Seeing the puzzled look on our faces, he elaborates:

"The best example I've heard when someone is trying to explain it in layman's terms, is to imagine a circular table. Everyone has got their places laid around this. When it is all laid and neat, I can rotate this table and it will look the same. But as soon as someone sits down, lifts something up, say a napkin, it becomes different. I cannot rotate it anymore and the symmetry is broken. But this can happen anywhere around the table, there is no fixed place where it can happen and that's *spontaneous* symmetry breaking."

The nucleons – protons and neutrons – are made up of three quarks each. However, their mass is much greater than what would be expected from adding up the masses of the constituent quarks. "All that additional energy of a nucleon is coming from the binding, from the gluons," explains Prof. Libby. Thus, real fermions only carry a tiny amount of the mass of what we see as regular matter. The rest has to do with the gluons and the energy they have due to strong binding. "So it is a bit of a misnomer when people say that the Higgs mechanism explains the mass of everything. Gluons have energy as an equivalent of mass," says Prof. Libby, thus busting the myth of the "god particle" being responsible for all mass.

"Another reason the Higgs mechanism is not responsible for all the mass in the universe, is that regular mass accounts for only 5% of the energy of the universe," he points out. To explain the observed gravitational effects on the visible, regular matter, cosmologists have hypothesized the existence of dark matter, which is not explained by the Higgs mechanism. "The Standard Model is incomplete, or an approximation to a higher theory, because there is no candidate for the dark matter in the Standard Model," he adds animatedly.

Although six theorists were, independently, involved in the formulation of the Higgs mechanism, the Nobel Prize Committee chose to recognise only Peter Higgs and Francois Englert.

Prof. Libby feels this was slightly unfair: "The award seems fair given the no-more-than-three-living rule, but Tom Kibble – born in Madras – and

collaborators did make a significant contribution, which has been recognised by other prizes for this work, such as the 2010 Sakurai prize. They should have been recognized with a Nobel."

We also spoke to Prof. Balakrishnan, who concurs. "Hagen, Kibble and Guralnik were really unfortunate, as the rules do not permit more than three recipients in a given year. It is reminiscent of the 1965 Prize, when Richard Feynman, Julian Schwinger and Sin-Itiro Tomonaga were honoured for quantum electrodynamics, while Freeman Dyson 'missed the bus'. Englert's collaborator R. Brout, too, missed the award, as he passed away just a few years ago," he observes.

However, the nature of research in modern-day science, especially in a field such as particle physics, is collaborative, and progress is incremental. Two armies of about 3,000 physicists each worked on the two detectors at LHC: the ATLAS and the CMS. While the Nobel Prize citation mentions this experimental work, there is a feeling that the prizes could have acknowledged it too.

Prof. Balakrishnan agrees that this is, on the whole, unfortunate. "The award unfortunately did not extend to the massive experimental effort by the groups at CERN that worked so hard and with such single-minded devotion and organization to hunt the elusive Higgs boson down." He expresses the hope that some time in the near future, the on-going CERN effort will be honoured with a Nobel Prize, when the present discovery is placed in perspective and buttressed by other related discoveries. For example, the theory admits more than one Higgs boson, and it is possible that the others too, would be found.

If and when this happens, it will be a paradigm shift as far as the Physics Prize is concerned. So far, it is only the Peace Prize that has ever been given to organizations such as the International Red Cross. "But now the situation may actually call for organizations and labs themselves to be honoured," points out Prof. Balakrishnan.

Despite this, he has slightly ambivalent views when it comes to this year's award. "The Prize this time has honoured a deep and pristine *idea* that was purely an idea in field theory at the time it was mooted, long before the Standard Model fell into place, pre-dating even the electroweak unification. As such, it is of a very different nature and character than the technical tour-de-force represented by the experimental detection of the Higgs particle almost 50 years later," he says.

Further, he points out that finding the Higgs boson was not a de novo discovery. He compares its detection, from the trillions of collisions and the petabytes of data, to finding a needle in a haystack. However, he says, "the *theory* is what asserted, in the first place, that the haystack would contain a needle at all. Moreover, the bounds on the mass placed by theory and phenomenology very helpfully pointed out the specific corner of the haystack in which the needle was likely to be hidden."

Giving examples of several other experimental discoveries which he feels were truly unexpected and revolutionary, he says, "This was not at all like the experimental discoveries of parity-violation, time-reversal symmetry violation, the quantization of the Hall effect, and many others. To give a geographical analogy, this was more like the conquest of a very difficult mountain peak by a well-equipped and well-planned expedition, rather than the unexpected discovery of a whole new continent."

Prof. Libby counters: "Knowing where to look for the Higgs comes largely from precision electroweak data, principally the masses and widths of the Z and W bosons and the top quark, where the level of accuracy is sufficient to probe the loop corrections – including those with a Higgs – to these observables. This was mainly done by experiments at LEP/CERN and at the Tevatron/Fermilab. Neither have received any recognition from Stockholm," he points out.

"Recognition of the theory is just, but I think you may sense where some of the experimentalists' bunker mentality on this topic comes from. Particularly given the last accelerator experiment to win is UA1 in the early 1980s. For example, at LEP, the painstaking work reducing the uncertainties in the mass of the Z due to those in the beam energy involved studying train tables and understanding the influence of the tides in

Lac Leman, which is a very different type of accomplishment but ingenious all the same," he says, giving examples of the kind of painstaking work experimentalists do.

"There should have been some recognition of these feats," agrees Prof. Balakrishnan. "But history is full of these 'errors of omission.' Madame Wu should perhaps have got the Nobel Prize because, after all, the direct demonstration of the violation of such an 'obvious' symmetry (parity) doesn't happen every day."

This discovery of parity violation led Robert Marshak and George Sudarshan and later, Richard Feynman and Murray Gell-Mann, to propose a new mechanism called V-A for weak interactions. In this theory, the weak interaction acts only on left-handed particles – those with the direction of their spin vector opposite to their direction of motion. Since the mirror reflection of a left-handed particle is right-handed, this explains the violation of parity.

However, as Prof. Balakrishnan points out, "It's ridiculous that all the other weak interaction breakthroughs, starting from Becquerel right up to Rubbia and Van der Meer have been recognised with a Nobel, but not V–A. Sudarshan and Marshak should certainly have got it for V–A."

Thus, the Nobel Prizes, though unmatched in their prestige, are certainly not the sole measure of, or the sole reward for, scientific accomplishment.Subrahmanyan Chandrasekhar, a Nobel Laureate himself, often quoted from a letter of his friend Edward Milne: "Posterity, in time, will give us our true measure and assign to each of us our due measure and humble place; and in the end it is the judgement of posterity that really matters. He really succeeds who preserves accordingly to his lights, unaffected by fortune, good or bad. And it is well to remember that there is in general no correlation between the judgement of posterity and the judgement of contemporaries."

Watching as the Soil Breathes

By Sneha Reddy and Poorna Kumar

On the timescales of history, the discovery and scientific acceptance of climate change are very recent events. The scientific discovery of climate change began in the early nineteenth century when the natural greenhouse effect was first identified. Researchers then dared to venture that low levels of carbon dioxide might explain the ice ages of the past. Later, at the turn of the last century, the idea that humans might be responsible for climate change was proposed by Svante Arrhenius, but it was deemed faulty and brushed aside at the time. It took until the 1960s for people to be convinced about the warming effect of carbon dioxide. Only then, with the advent of the environmental movement, did scientists began to look closely at changes in carbon dioxide levels over the ages and the factors which contributed to those changes.

The levels of carbon dioxide in the atmosphere are instrumental in tracking climate change – but they are not the only parameters by which scientists predict and track global warming. The burning of fossil fuels releases carbon dioxide into the atmosphere and causes it to heat up, and this heating triggers noticeable changes in other processes too.

For example, increased atmospheric temperatures have an effect on soil respiration, or the production of carbon dioxide when soil organisms respire. This natural process, in which carbon dioxide is released from the soil into the atmosphere, is also in a "positive feedback system" with global climate change – which means that soil respiration rates can be affected by climate change, and in turn, respond by accelerating climate change. Ben Bond-Lamberty and Allison Thomson, researchers at University of Maryland's Joint Global Change Research Institute, have found that soil respiration has increased by about 0.1 percent per year in the two decades from 1989 to 2008. Thus, as the atmosphere becomes warmer, plants and microbes in the soil release more carbon dioxide.

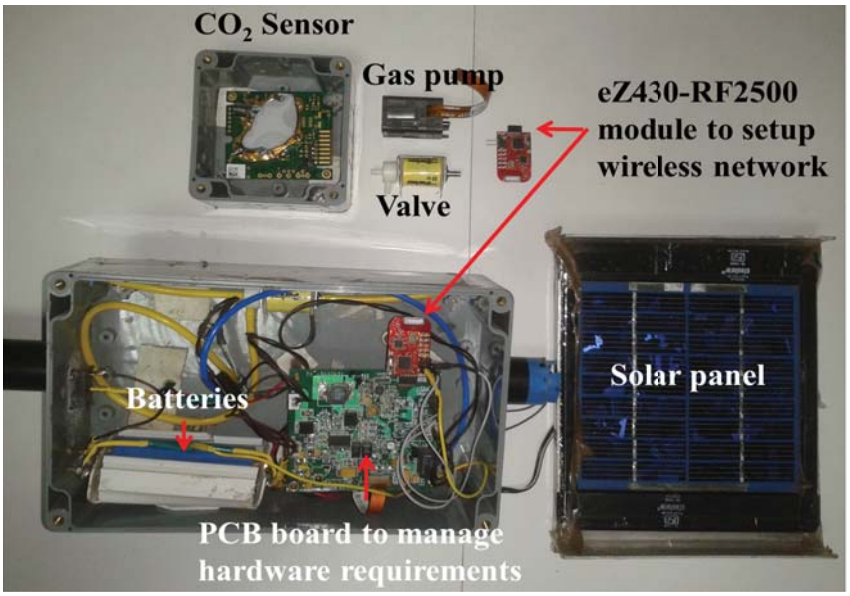
The link between carbon dioxide levels in the soil and global temperatures makes data regarding the carbon dioxide levels in the soil very valuable, as it can advance our understanding of global climate change. I visited the Electrical Sciences Block to interview Vaibhav Pratap Singh,

Vaibhav with the soil carbon dioxide sensor module.

a research student in the department who has worked on a wireless sensor network that can give us just this data by monitoring the levels of carbon dioxide in soil.

Vaibhav's device measures and wirelessly communicates the carbon dioxide levels in the soil. Using these measurements, he can throw light on the variations of soil carbon dioxide levels with seasons, temperature conditions and geographical locations. For his project, Vaibhav won the Bayer Young Environmental Envoy 2013 (BYEE 2013) competition, which is held in cooperation with the United Nations Environment Programme (UNEP), and participated in the Bayer environmental summit in Germany, from 10th November to 15th November 2013, along with forty eight others from eighteen other countries.

At the start of the interview, I ask Vaibhav to explain how the device was built and what it does. He explains that the set-up for the device consists of a carbon dioxide sensor chamber covered with a membrane that is "semipermeable" – it allows only certain gases to pass through it, and keeps others out. The sensor measures the levels of carbon dioxide and converts these measurements into electronic signals. But there is another hurdle here: the electronic signal has to be transmitted over long distances, since it is impractical to collect data from the forest or grassland where the sensor is.



Vaibhav solved this problem by employing a wireless network which sends data to be recorded on remote servers. When these remote servers are interfaced with a personal computer, one can analyze the data and generate graphs that depict the variation of carbon dioxide in the soil.

Like most technology that is developed for remote areas, Vaibhav's soil carbon dioxide sensor comes with a familiar challenge: power. The sensor must draw its energy from somewhere, and in the far-away areas where it is to be deployed, the most readily available source of energy is the Sun. Vaibhav explains that the carbon dioxide sensor is powered with a battery, and the device is equipped with a solar panel so that the battery can be recharged. The device is also fitted with a pump. This, Vaibhav tells me, is because the device is designed to monitor not just the levels of carbon dioxide in the soil, but also its levels in the atmosphere.

Has the sensor been used yet to collect data? Vaibhav answers, "Yes, we conducted our first round of data collection from 28th March to 8th April in 2012. We buried the sensor chamber at a depth of 20 centimeters. Every three hours, the levels of carbon dioxide in the soil were measured. We found that the levels of carbon dioxide in both the soil and the atmosphere increase with an increase in temperature," Vaibhav adds. Pointing to the graph that shows the variation of carbon dioxide levels with time, he continues, "You can see this by the spikes at 10 a.m., 1 p.m. and 4 p.m. These spikes are linked to the role of microbes in breaking up carbon compounds in the soil to produce carbon dioxide."

He elaborates, "After a reading of soil carbon dioxide level is taken, the pump is turned on. The pump pushes out the air that is already in the sensor chamber, and pumps in air from the atmosphere. The sensor then measures the level of carbon dioxide in the atmosphere. After this is measured, the atmospheric air is pumped out. There is also a valve that is built into the device to enable calibration. After air is pumped out of the chamber, the valve is opened, and this brings any remaining air in the chamber in contact with soda lime, which absorbs all the carbon dioxide. Now, the levels of carbon dioxide in the chamber are known to be zero, and the sensor output can be appropriately calibrated."

So what's next? Vaibhav answers, "Right now, we've finished designing the hardware for the project and are in the experimental phase of it. One challenge for us is to reduce the power consumed by the sensor so that its battery lasts longer. This is particularly important for long–term experiments. We also want to be able to receive data from the sensor on mobile phones, for which we'll have to incorporate GSM. Another major challenge is to make the measurement precise and accurate, for which we have to eliminate errors in calibration. The goal of the project, ultimately, is to build a low-power, low-cost device to study how the level of carbon dioxide in the soil varies with seasons, temperature and geographical locations." Vaibhav hopes to receive support from Bayer in taking his project further. Bayer's international presence could also help them collect data from different parts of the world. Vaibhav envisions his product as one that can help a spectrum of people across the world, from environmental researchers and organisations to agricultural universities and farmers.

Environmental consciousness and technological advancements can make for strange bedfellows. And especially at a university like IIT Madras, which has a beautiful and fragile natural ecosystem in tenuous equilibrium with rapid development, Vaibhav's research and the recognition it has received are an encouraging affirmation that science could possibly marry the two.

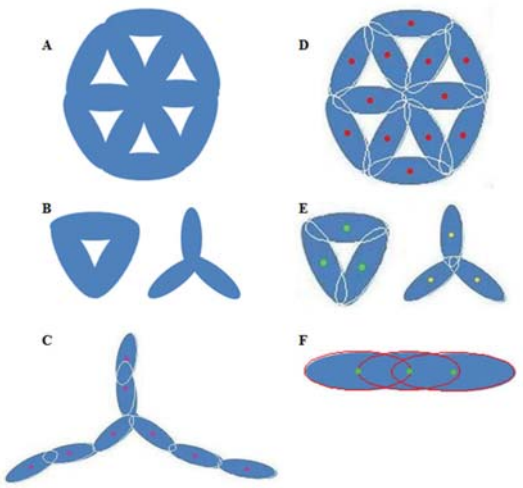
Cancer, Colloids and Computer Vision

By Raghavi Kodati

Cervical cancer kills nearly 73,000 women every year in India, many of them from rural areas. Screening for cervical cancer, which takes around ten years to fully develop, can help detect the cancer in its incipiency and therefore prevent it from becoming dangerously malignant. In a Pap smear test, which is usually used for cervical cancer screening, cells are taken from the uterine tract and studied by cytologists. Cancerous cells look nothing like a normal cell. They often have multiple nuclei, are abnormally elongated and can be visually identified by trained lab experts. But this test requires a lot of resources – laboratories, equipment, facilities for the transport of specimens and, importantly, trained people who can visually detect cancerous cells from the smears. The test is also very expensive, which limits its reach.

To wipe out cervical cancer in a developing country like ours, there is a need for cost-effective technology for large-scale screening. In the Department of Chemical Engineering at IIT Madras, there is a project underway which could provide just that. Professors Sridharakumar Narasimhan and Basavaraja M. Gurappa are working on an automated algorithm for the screening of cancer cells. By doing away with the necessity of having cytologists search for and find cancerous cells in Pap smear tests, computer algorithms can simplify the process of screening for cervical cancer, making the test affordable and accessible for large numbers of women across the social strata. As Prof. Sridhar puts it, if the visual identification of cancer cells could be automated, a cancer screening test wouldn't need more than a janitor and some equipment.

For such automation, we need a computer to perform the role that a cytologist's eye and brain play in spotting cancerous cells in a Pap smear sample. More precisely, we need "computer vision," a field that involves the study and development of computer methods for acquiring, processing, analyzing and understanding images. Cancer cells are elongated in shape, and can be approximated mathematically as ellipses, which can then be detected by computer algorithms.



Ellipses detected using the method proposed by Suyog.

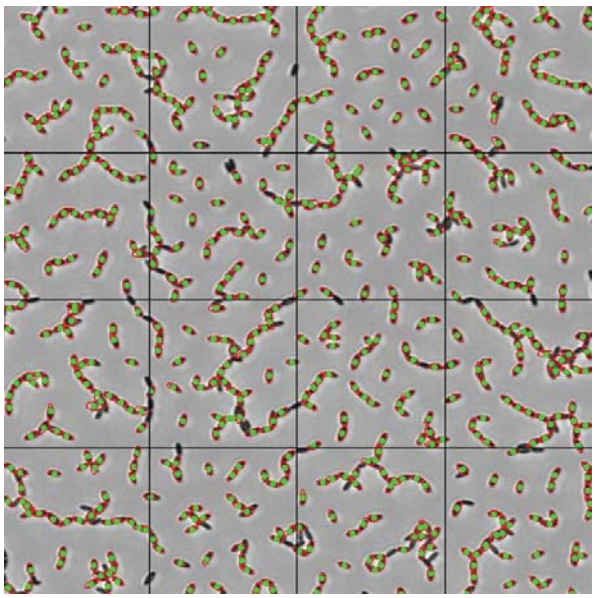
Suyog Sawala, a B.Tech from the Department of Chemical Engineering at IIT-M who graduated in 2013, worked along with Prof. Sridhar and Prof. Basa on this integral part of the problem – the detection of elliptical shapes by computer vision – as his final-year project. This involves lengthy and complex computations, and is a challenging problem in computer vision. To complicate matters, the real world is far from ideal and elliptical objects are never perfect – they come in altered shapes and in forms that are clumped together, or "occluded." Suyog's work focuses on improving existing methods of detecting elliptical objects in two-dimensional images speedily and efficiently, and is highly important for Prof. Sridhar's work on cancer detection.

For his project, Suyog was recognised with the "Best Project" award in the Mechanical Engineering division at the 2013 Jed-i Project Challenge, which is an annual event aimed at identifying and showcasing the best final-year engineering projects, held at the Indian Institute of Science, Bangalore. Members of the jury at the event comprised experienced industrialists and researchers from different disciplines, while participants showcased a whole spectrum of projects from prosthetic arms to soil analyzers to bio-energy production from waste.

Delving into the details of Suyog's work, Prof. Sridhar says that the geometrical principles underlying basic shape detection through computer vision are simple and intuitive. Shapes are detected using techniques like "Canny edge detection" and the "Hough transform." He explains: "Suppose you are looking for a line in an image. First, you would identify all the pixels on the edges of different shapes in the images. Edge detection by a computer is based on differences in the brightness of image components. For example, in the image of a blood smear, the sharp contrast between the cell and the surrounding fluid can be used to identify the edges of the cell. Every pixel on the edges is given a geometric position, an x-coordinate and a y-coordinate. To detect lines, the computer would then need to identify collinear edge pixels – pixels which lie in a straight line."

He continues: "A line can however, can be defined completely by only two points. This is not true when identifying ellipses, as a minimum of five parameters, namely, the axes lengths – major and minor, the orientation of the ellipse, the position of the centre of the ellipse – its x- and y-coordinates, are required to uniquely identify it. Thus, the problem of identifying ellipses is computationally intensive while being sensitive to the aspect ratio of the ellipse. Here, the Hough transform technique comes to the rescue. Imagine any two edge pixels and assume they are the end-points of the major axis of some ellipse. Then consider any other edge pixel to be lying on this ellipse. These three pixels together define a unique ellipse. Now count the number of object pixels through which this ellipse passes. If this count is greater than the threshold, our assumed ellipse is actually an ellipse and is thus successfully differentiated from the rest of the pixels."

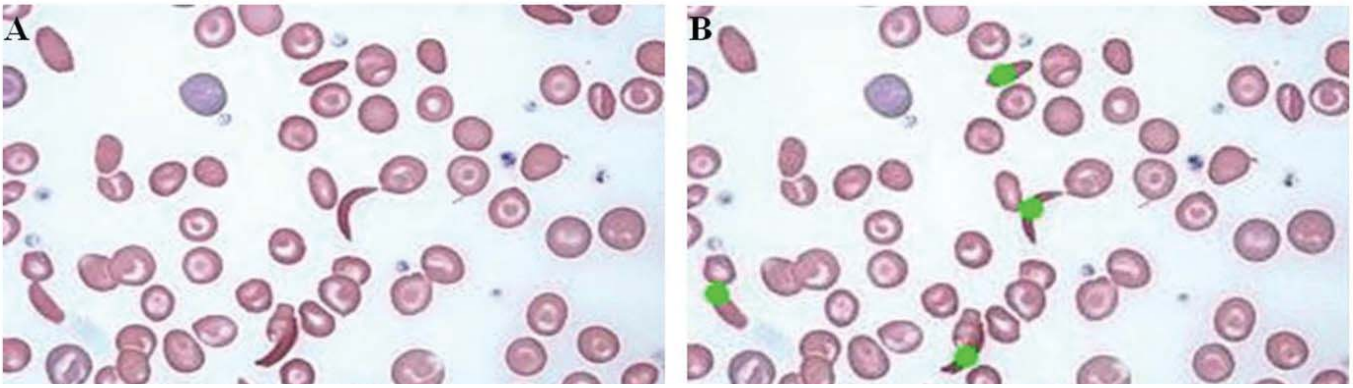
However, these generalized versions of the Hough transform are in a "high-dimensional" space – space that has more dimensions than the usual three. Working with such spaces can consume a lot of a computer time and memory. There are other challenges too.



Elliptical particles detected in an optical microscopy image of colloidal particles at water-oil interface.

Says Suyog, "Detecting shapes when a clear outline is not visible, detecting individual objects in a complex cluster-forming pattern, detecting them faster, making the algorithm robust to noise, while also being able to adapt to detect slight variation in shapes are part of the challenge." Suyog, along with Professors Sridhar and Basa, came up with new algorithms that are not only computationally less demanding but are also effective in the presence of noise or occlusion in the image. Their algorithms are also quite successful at detecting slightly altered shapes – for example, the sickle-shaped blood cells that are symptomatic of sickle cell anemia.

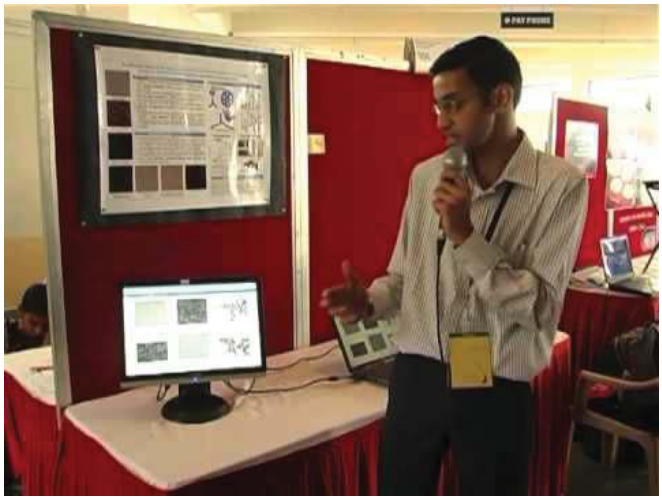
So why was a project involving image processing and cancer screening taken up in the Department of Chemical Engineering? Suyog answers: "The project was initially started because of its major applications in colloidal sciences – shape detection algorithms could be used to quantify the number density, size and orientation of colloidal particles from microscopy images. As the project reached its primary milestone, its applications in other areas were explored to realize its full potential. Cancer cell detection was one such area."



Red blood cells with sickle cell anaemia identified using the proposed method.
IMAGE CREDIT: Keith Chambers, www.sicklecellanaemia.org

Although Suyog has now graduated from IIT-M and is working as a professional with Shell, he is simultaneously working with his project advisors towards publishing a paper on his project work, and on finding feasible ways to commercialize this project. If Prof. Sridhar and Prof. Basa find ways to successfully apply Suyog's work in cervical cancer detection, it will contribute towards making the screening tests cheaper and more accessible. And if that happens, it could make the lives of millions of Indian women a little brighter.

(With inputs from Professors Basavaraja M. Gurappa and Sridharakumar Narasimhan, Suyog Sawala and Adarsh Chavakula, a B.Tech third-year student of Chemical Engineering and a member of the team working on cancer detection.)



Suyog during his presentation at the Jed-i Project Challenge.

Nanomaterials for Cooling

By Ankur Agarwal

Small changes can have very large effects. Even if "small" happens to be in the realm of nanometres, it can have effects powerful enough to transform the way we live and consume energy.

Subhashini, Rashmi and Shreya, three researchers who work in the Alternate Energy and Nanotechnology Lab, in the Physics department of IIT Madras under the supervision of Prof. Ramaprabhu, have been working on the development of alternate energy systems using nanotechnology. With a shared commitment to develop clean energy, they have caught the eye of industry and academia alike with their recent research involving carbon nanotubes.

Nanomaterials are structures of the size of a few nanometres – a nanometre is a billionth of a metre – which have excited the scientific community for long because of the variety of ways in which they can alter the properties of other materials.

The most popular of these are carbon nanotubes and graphene, both of which, though allotropes of carbon, differ in their molecular structure. These nanomaterials can do wonders when mixed (dispersed) in a medium which is a combination of base fluids and solvent.Prof. Ramaprabhu's research group has successfully used nanomaterials to increase the thermal efficiency of such a medium. This has applications in industry, where it can be used for cooling purposes.

The research group manufactured the carbon nanotubes, "functionalised" them to increase their dispersion ability and finally combined them with base fluids to do a thorough analysis. Their success has led to widespread acknowledgement of their work, with TATA Steel signing a Memorandum of Understanding with IIT Madras.

The technology needs to be developed further to reach its usable form, as producing carbon nanotubes is expensive, costing about Rs. 2500 for every gram. Meanwhile, industries are investing heavily in their research divisions to develop cheaper ways of producing carbon nanotubes. Prof. Ramaprabhu estimates that it would take another five to ten years for carbon-nanotube-based solutions to replace common heat exchanger fluids and coolants, and microchip coolant coatings. The pace of development, of course, depends on quality research work being done by research groups like the one here at IIT-M.

Shrinking Spectroscopes

By Sachin Nayak and Aroon Narayanan

Nanophotonics, the study of the behavior of light at the nanometre scale, has applications in the manufacture of silicon and gallium arsenide wafers and leads to faster, smaller devices with a higher bandwidth of communication and also a higher level of integration in integrated circuits.

The Centre for Nanoelectromechanical Systems and Nanophotonics (CNNP) at IIT Madras pursues cutting edge research and development for developing socially relevant systems in the sectors of food safety, health and communication.

Table-top spectrometers can be used to detect food adulteration and to find the composition of soil in agricultural fields. Usually, the soil is sent to regional testing centres for testing, which takes a long time.

An interesting project currently being undertaken at CNNP is the miniaturization of spectroscopes with microelectromechanical systems (MEMS) technology by Dr. Shanthi Bhattacharya. Most of her current research revolves around the design of spectroscopes.

I met her to learn more about her research into optical MEMS technology and its role in miniaturizing spectroscopes.

Absorption spectroscopy is a widely used technique to find out how much of a substance is present in a given sample. Each substance has a particular frequency called its resonant frequency. In absorption spectroscopy, light in a range of wavelengths is allowed to fall on a sample and it absorbs only that particular wavelength which corresponds to its resonant frequency. By analyzing the spectrum of light transmitted and looking for wavelengths that are absent, one can establish the nature of the sample. Spectroscopes with a high resolution and an ability to detect objects over a large range of wavelengths are available in national labs.

A question that naturally arises at this point is why there is a need for research on the design of spectroscopes. Dr. Bhattacharya explains: “Large spectroscopes are extremely expensive and are not for specific applications. Also, these can only be installed in large laboratories. Therefore, we need smaller spectrometers built for specific applications like testing food or soil samples.”

To go about making a spectroscope smaller, one must first know the key elements that go into the making of a spectroscope.

The spectroscopes of the kind used in Dr. Bhattacharya’s lab have a splitting element, a partly translucent mirror and reflecting mirrors. The splitting element is something like a prism that splits light into its different wavelengths. Of course, instead of prisms, diffraction gratings are used in spectrometers.

Microelectromechanical systems enter the picture when materials that can be used to make the grating, or the mirror, for the spectrometer are needed. MEMS are small and lightweight, and can be used to make the grating and the mirror. The structural dimensions of MEMS are of the order of the wavelengths of visible and infrared light, which is why they can be used to make the diffraction grating. Also, the starting materials for MEMS fabrication have smooth, reflective

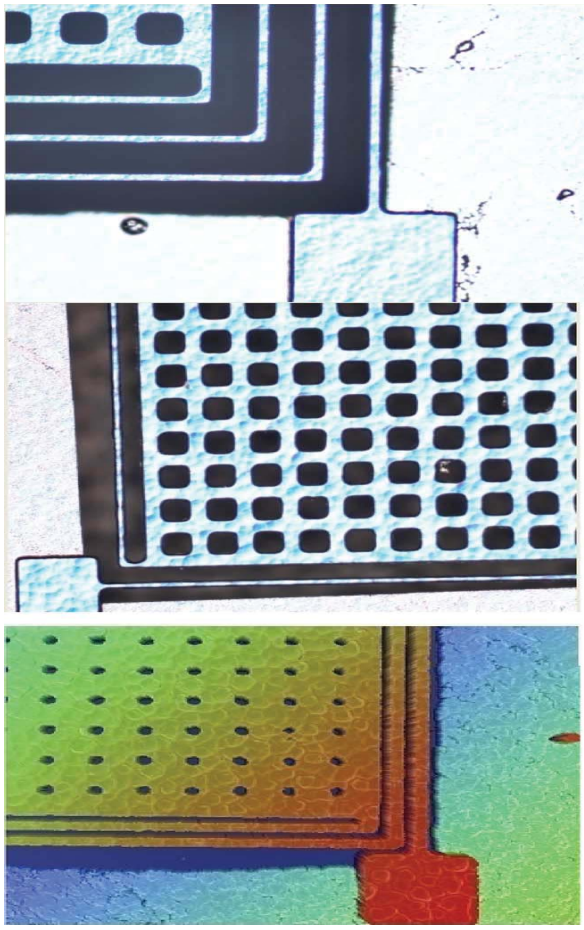


IMAGE CREDIT: Prof. Shanthi Bhattacharya

Optical microscope pictures of micro-mirror structures with three folds (top) and a single fold (middle). Surface profiler image of a two-fold micro-mirror structure (bottom).

surfaces and the reflectivity of the surface can be enhanced or retained, making it an ideal mirror. The resolution of spectrometers with MEMS gratings is small. Also, these are small in size and are specific to the substance which is to be detected. However, MEMS gratings can be cheaply produced. Through batch processing, many of these gratings can be produced in a single wafer.

The technical name of the project is "Design of Lamellar Grating for Fourier Transform Spectroscopy Systems" and Dr. Bhattacharya reveals that she wishes to develop an on-chip solution for the whole problem. The ultimate aim of this project, she indicates, will be to fabricate a completely miniaturized on-chip Fourier Transform Spectroscope.