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CODE FOR THE STARS:

PROGRAMMING THE WORLD'S LARGEST TELESCOPE

P.14

ABOUT THE ISSUE

The transition into a post-Covid world is only just starting. Economies opening up, people cautiously venturing outside their homes, life slowly trying to get back to a normal. The question on everyone's minds though - is that going to be a very new kind of 'normal'?

After our Covid-19 themed issue in April, we at IIT Tech Ambit are also writing on the science and tech we used to - however in line with the current necessity of always being in the side of caution, we keep an eye out for progress in tackling the pandemic - Jasmine writes about the robotics that's helping doctors and medical staff, with a closer look at Asimov Robotics.

Our 'usual' beat of science and tech starts with a feature story on something far from the usual - the biggest telescope in the world, the Thirty Metre Telescope, set to reveal revolutionary new insights into the formation of our universe. It's going to take some advanced Software, with an Indian flavour, to get there though.

Shaurya gives us a glimpse into the achievements and innovations of IIT Kharagpur's Formula SAE research group, TeamKART; Jasmine gives us an intriguing in depth look at the changing landscape of agriculture in India - and how robots are going to herald that change. And finally, we have the third and final part of our well-received trilogy, the State of Hyperloop. We look at the Indian scenario and how the first ever example of the ground-breaking technology might have come agonisingly close to being in our country.

We'd like to thank each and every one of you readers, supporters and well-wishers, in contributing to the success of our previous issue. We hope that with your continued support, we can continue to put out stories we truly believe in telling, and that these can reach more and more of you.

May the force be with Tech.

Pranav Krishnan

Editorial Head

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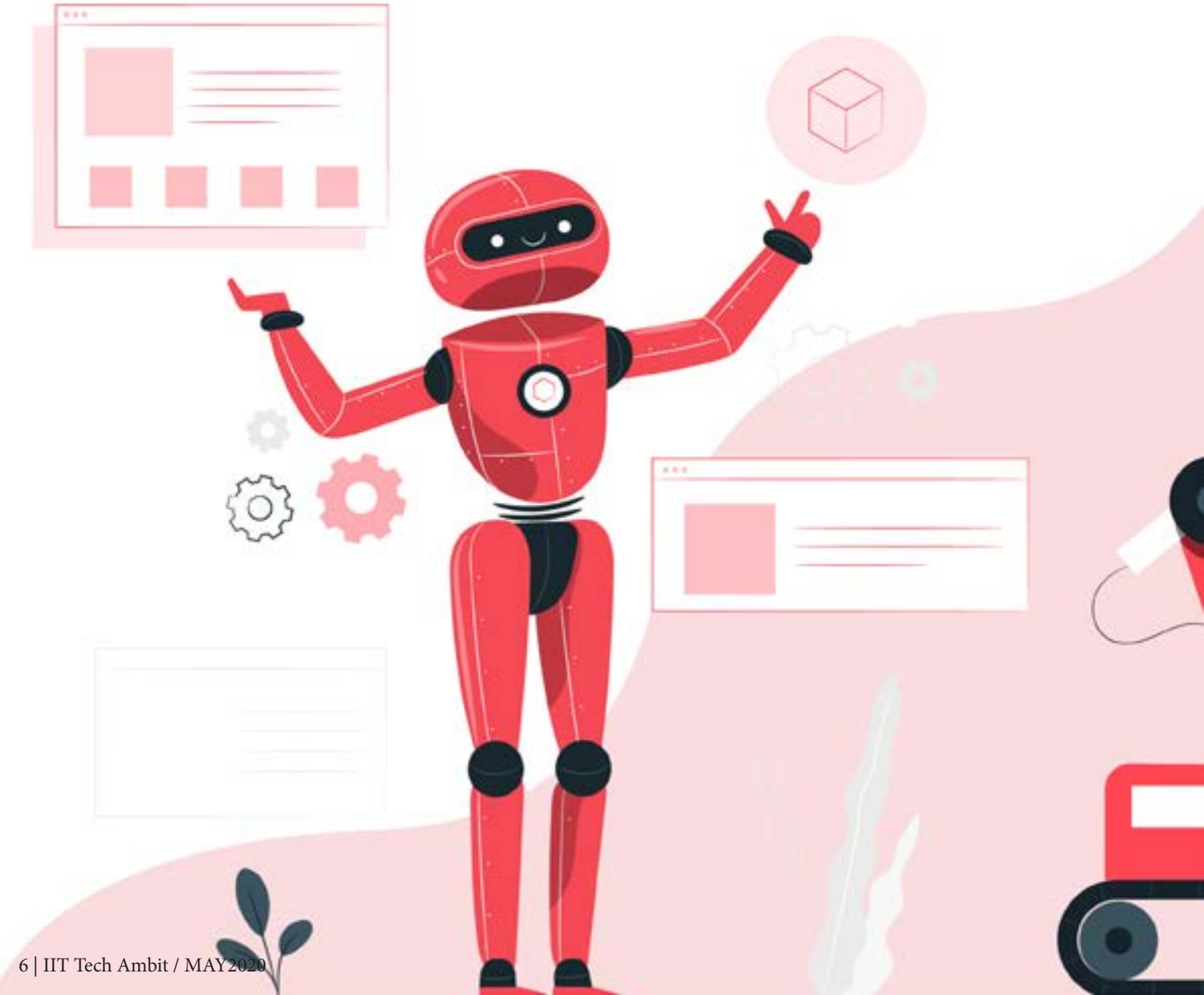
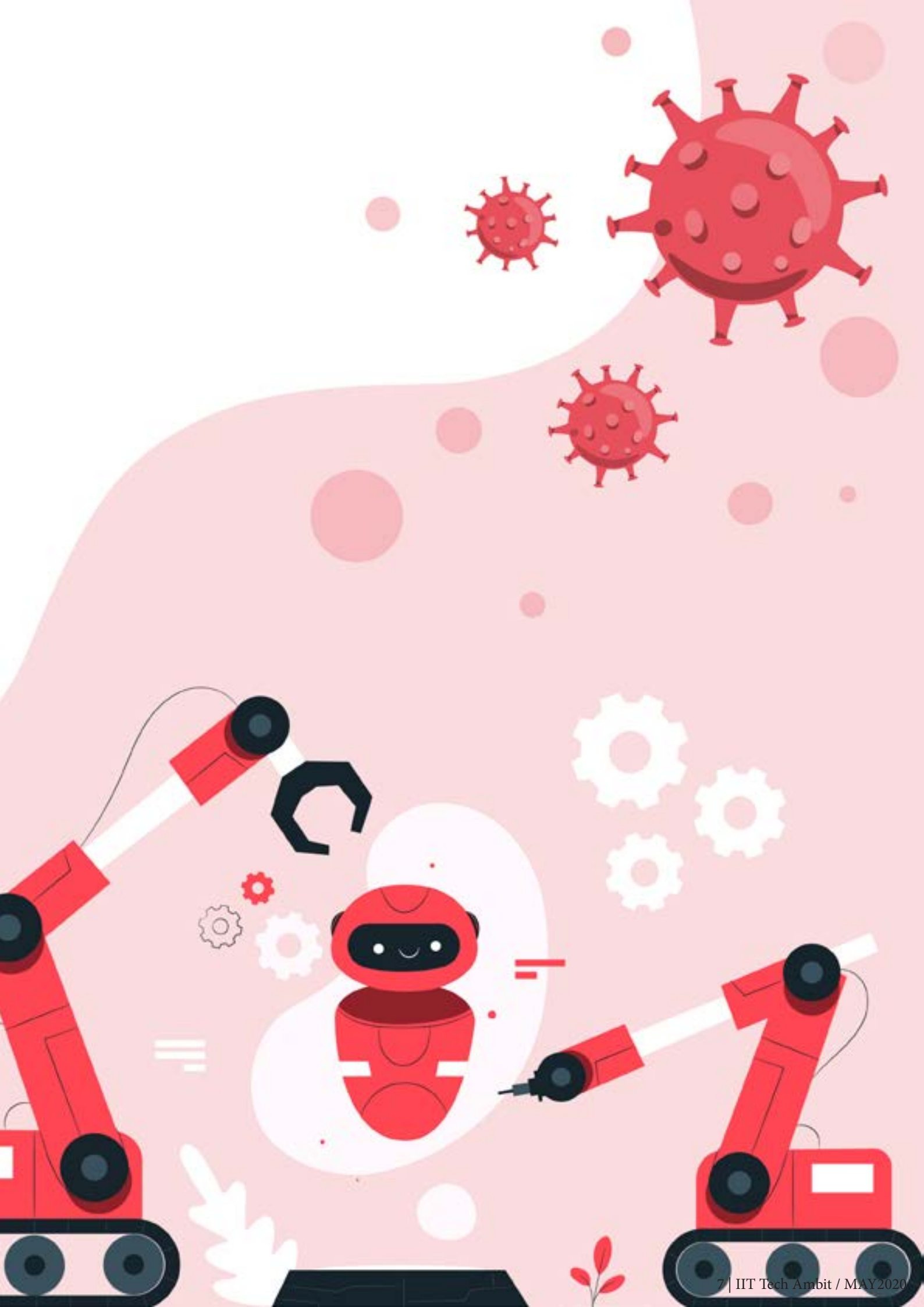
COVID19: Medical Robots Working Alongside Hospital Staff

Jasmine Jerry

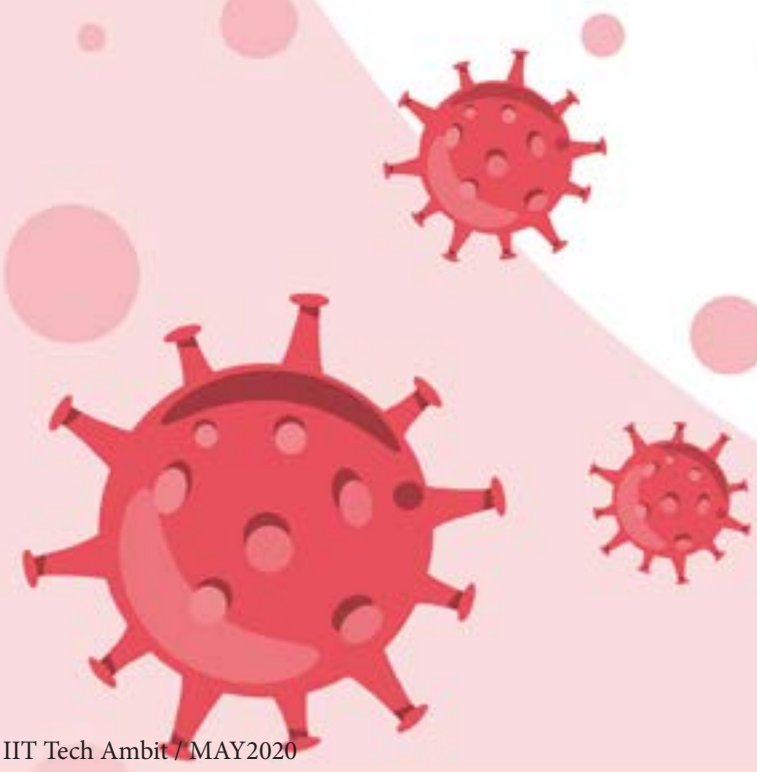




KARMI

Kochi-based ASIMOV Robotics debuted its KARMI-Bot, an intelligent service robot for isolation wards developed under the MAKE IN INDIA initiative, with the added feature of being able to disinfect the premises using ultra-violet radiation. KARMI-Bot is capable of autonomously navigating inside the isolation ward to transport and dispense food and medical supplies for patients under care and thereby minimising human involvement. They also can converse with the patients as well as initiate video conferencing between patients and the human caregiver from a remote location. The robot is capable of disinfecting the used items during the return journey to home station.

KARMI-Bot comes with an android application to monitor and control the robot in manual mode from a distance. Users can configure the destination points using a user interface from a built-in touch screen and remote monitor. In addition, KARMI-Bot is equipped with high power detergent spray for cleaning the infected areas by controlling from a remote location. The self-charging KARMI-Bot has a maximum payload of 20 kilograms and a power backup that lasts up to 5 hours. The company grabbed attention on social media recently with a video of its two Sayabot androids dispensing cleaning materials and displaying information related to the coronavirus.



Talking Tech

Tech Ambit got in touch with the founder and CEO of ASIMOV Robotics, Mr Jayakrishnan, who let us in on the details behind this wonderful feat.

Jasmine:

What was the motivation behind KARMI-bot? When did development on the robot start?

Mr Jayakrishnan:

Being a robotics company focused on medical and healthcare applications, we have always been keen on finding solutions to the difficult and dangerous problems in this area. We started development on the robot during the outbreak of Nipah virus in Kerala. When the Nipah virus came a second time to Kerala, we conceptualised an idea of performing some therapeutic and caregiving tasks inside the quarantined ICU using the humanoid robotic platform we have. This use case has also been patented.

Incedingly, COVID was reported in Kerala for the first time in India. However, despite having the information spread through visual media and news dailies, we found that the public hadn't been taking it seriously. To address this, we deployed two robots in our IT campus to spread awareness among the staff of IT companies as well as to distribute tissue paper, sanitisers and masks. This initiative was well received, and we continued this for 2 weeks. By this time, the situation has worsened, and most of the companies had moved on to the "work from home mode". We then decided to do something, more effective and useful. So we planned to develop a robot for dispensing food and medicine inside the COVID ward to help the health workers and save the use of PPE kits.

Jasmine:

How was development different for COVID-19?

Mr Jayakrishnan:

Unlike Nipah, the difference we could identify with COVID-19 was that it is not as life-threatening as Nipah, but spreads much faster. Thus, we developed a cost-effective system which is easy to transport and deploy. We approached the district health administration and then got connected to the Cochin medical college medical team. Upon interacting with them, we identified a few important design aspects: like the need for collecting trash and other used items, ability to withstand the frequent cleaning using detergent spray etc. We have designed a robot which has all these capabilities. That was how KARMI-Bot (meaning "Robot staff") was born. It is also equipped with targeted spray using disinfectants to protect

health workers before they clean any bodily fluid on the floor in the case of vomiting, coughing and sneezing by the patient.
Next, we identified sponsors for project KARMI-Bot so that it can be given free of cost to hospitals. Fortunately, we got an immediate response from Malayalam film Actor Padma Bhushan Sri Mohanlal, and the robot was handed over to Cochin medical college under his sponsorship.

Jasmine:

What roadblocks did your team face, and how did they overcome them?

Mr Jayakrishnan:

Initially, we had faced a shortage of spare parts and difficulty with travelling and using office space inside the IT park. We then received special permissions from the Police and Park administration quickly upon request. As far as spare parts are concerned, we had dismantled the other robots in stock to address the issue.

Jasmine:

Would you be expanding nationally and internationally soon, during the pandemic?

Mr Jayakrishnan:

Definitely. We have 100's of orders in the pipeline from potential customers in India and abroad. We have completed the product and engineering design of four different models of KARMI-Bot. We are currently in the process of gearing up the production activities and scaleup the business through equity-based fundraising.

Minus Corona UV Bot

The company PerSapien has also developed a device which is an ultraviolet light (UV C-254nm) based robot that will enable sterilisation of hospital corridors, wards, Intensive Care Unit (ICUs) and patient rooms without exposing anybody to the contaminated environment. It comprises a UV-C lamp, mounted on a wheeled robotic platform. It is equipped with a camera that which gives the perspective from the driver's seat onto a digital screen and is operated (front-back, left-right) with a remote control to avoid any obstacles.

The developers were inspired by a similar product made by a Denmark company called 'UVD Robots' who sold their robots to hospitals in Wuhan, China, during the coronavirus outbreak there at $80,000-90,000. The UVD Robot is used as part of the regular hospital cleaning cycle. It aims at preventing and reducing the spread of infectious diseases, virus, bacteria, and other types of harmful organic micro-organisms in the environment by breaking down their DNA-structure using powerful ultraviolet rays. Minus Corona UV Bot would be priced much lower than this, stated PerSapien.

Airlens Minus Corona

The novel coronavirus can be deactivated using an alcohol-based sanitizer or washing your hands with soap and water. At an individual level, these are right solutions, but scaling up to the size of a city makes it impractical. Debayan Saha and Dr Shashi Ranjan, alumni of IIT Kharagpur and AIIMS respectively, have developed a device that purifies the air and eliminates the threat of the novel coronavirus. The duo in their venture, PerSapien Innovations, have used ionised water droplets released in the air to oxidise the viral proteins into non harmful molecules. The water droplets are

ionised using corona discharges, and these are ready to sterilise entire cities.

Dr Shashi Ranjan augmented the technology on the scientific research he did at NUS, Singapore. The team claims their technology uses an optimal combination of electric energy and water atomisation techniques to induce a charge on the water droplets, thereby creating oxidative 'Hydroxyl Radicals'. To travel the streets, they have developed a "Robo-Sapien" machine that can go to hospitals, bus stops, railway stations and other public places to sterilise surfaces which may cause the spread of coronavirus. The team has also come up with devices that can be used for buildings like homes and hospitals.

Sona 2.5

Sona 2.5 is a humanoid service robot developed by Club First Technologies. It can navigate in any complex environments autonomously using laser-based systems and uses modern technology to interact with users efficiently. Sawai Man Singh (SMS) Government Hospital, Jaipur, successfully tested the locally- manufactured Sona 2.5 to deliver food and medicines to Coronavirus patients.

ZAFI and ZAFI Medic

Propeller Technologies, a Tiruchi based software company, unveiled its Zafi and Zafi Medic robots on March 29 at the city's Mahatma Gandhi Memorial Government Hospital, equipped to deliver food and medicines to COVID-19 patients under quarantine. These robots are voice interactive and assist medical staff in bringing the required items without any human contact. Zafi has a payload of eight kilograms and can act as a medical assistant for contact-less consultations. Zafi Medic is a robotic rover, having a range of one kilometre and a payload capacity of twenty kilograms. It is designed to transport items within the hospital building and even has an option of a smartphone-based control.

Code for the Stars:

Programming the world's largest telescope

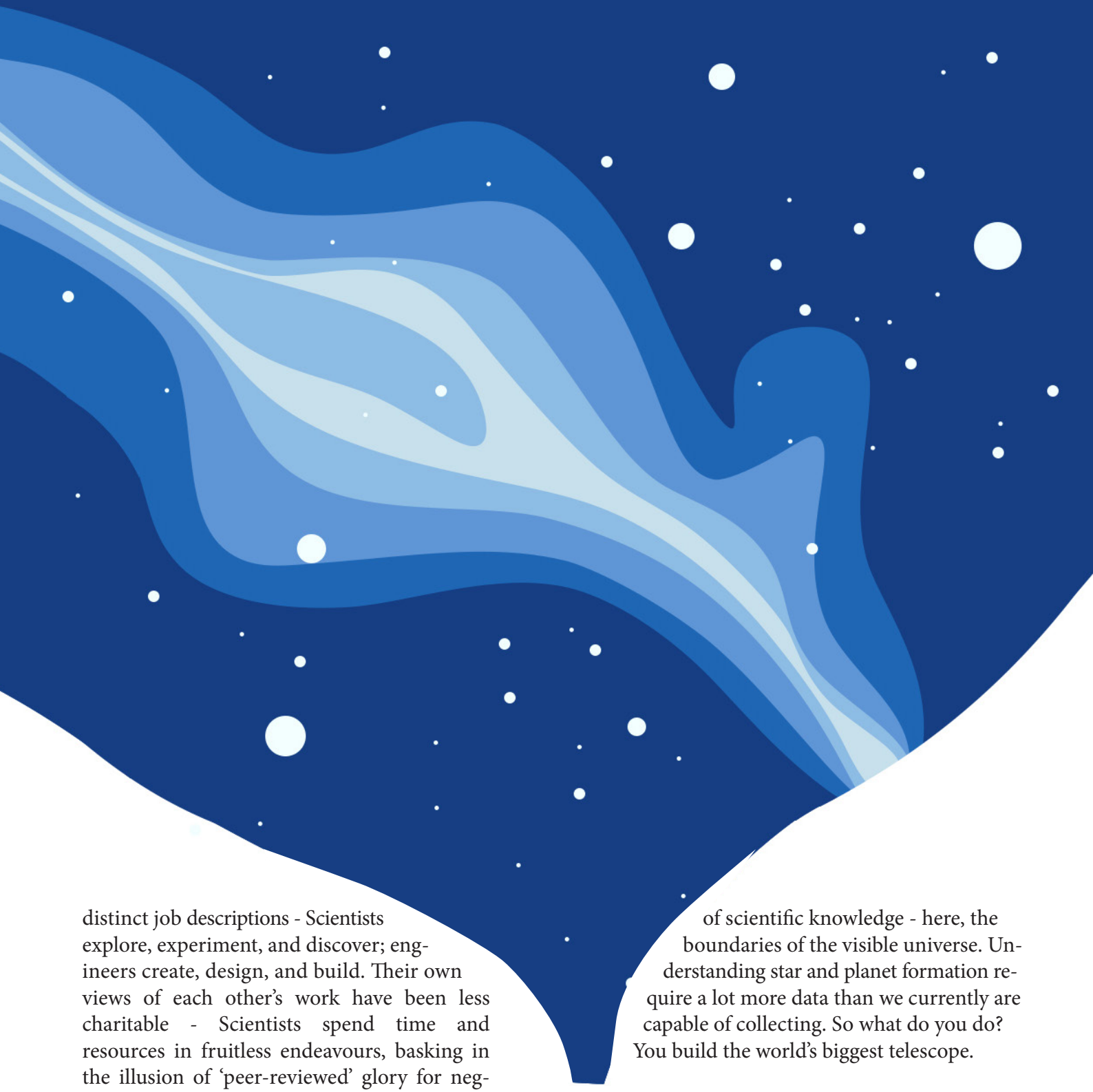
Pranav Krishnan

The Universe is cloaked in mystery. Galaxies collide and Stars form and die, oblivious to human existence. Our attempts to understand it require pushing the boundaries of what our science is capable of. Scientific achievements and technological innovations tend to come to the fore of the public consciousness on their culmination. The process and the hundreds of smaller innovations made along the way often go unnoticed - humanity is today without those small innovations. That's why this isn't so much a story about the Thirty Meter Telescope - an event that astronomers around the world wait for with baited breath - as the technology that's helping build it: software and hardware with a distinctively Indian flavour. But first a look at how Science research depends on Engineering, a field many scientists have been keen to distance themselves from, in the past.

The Start

At first glance, Mushtaq Ahmed isn't the type to work on telescopes. The self-described 'Mr. Scala' at ThoughtWorks, a global technology company, got himself hired at the company as a Business Analyst in Pune in 2008, before shifting to work full-time on evangelising his pet project. Scala is a high-level programming language that combines functional and object-oriented concepts and occupies a small niche in the market with those dissatisfied by its behemoth competitor, Java. The Chicago based tech consultancy inspired by the NAE's (National Academy of Engineering) 14 Grand Challenges of Engineering, decided it would work towards progressing the efforts needed to overcome these challenges. Revealingly, the challenge they chose to focus on was possibly the least ostentatious, yet equally crucial: Challenge 14 - Engineer the Tools of Scientific Discovery.

The relationship between Science and Engineering hasn't always been chummy. In the popular imagination, they have had



distinct job descriptions - Scientists explore, experiment, and discover; engineers create, design, and build. Their own views of each other's work have been less charitable - Scientists spend time and resources in fruitless endeavours, basking in the illusion of 'peer-reviewed' glory for negligible progress; Engineers sell their souls to Corporate in pursuit of short term, blinkered goals, lacking integrity or ethics. This stare-off has been forced into changing.

Science has found progress difficult when lacking the engineering expertise to design the instruments and systems required. Space has been the one bastion where, from the word go, collaboration was key. Both literally and metaphorically, the focus of greatest interest tends to be at the outer edges of scientific knowledge - here, the boundaries of the visible universe. Understanding star and planet formation require a lot more data than we currently are capable of collecting. So what do you do? You build the world's biggest telescope.

SIZE

30m in diameter

MIRROR

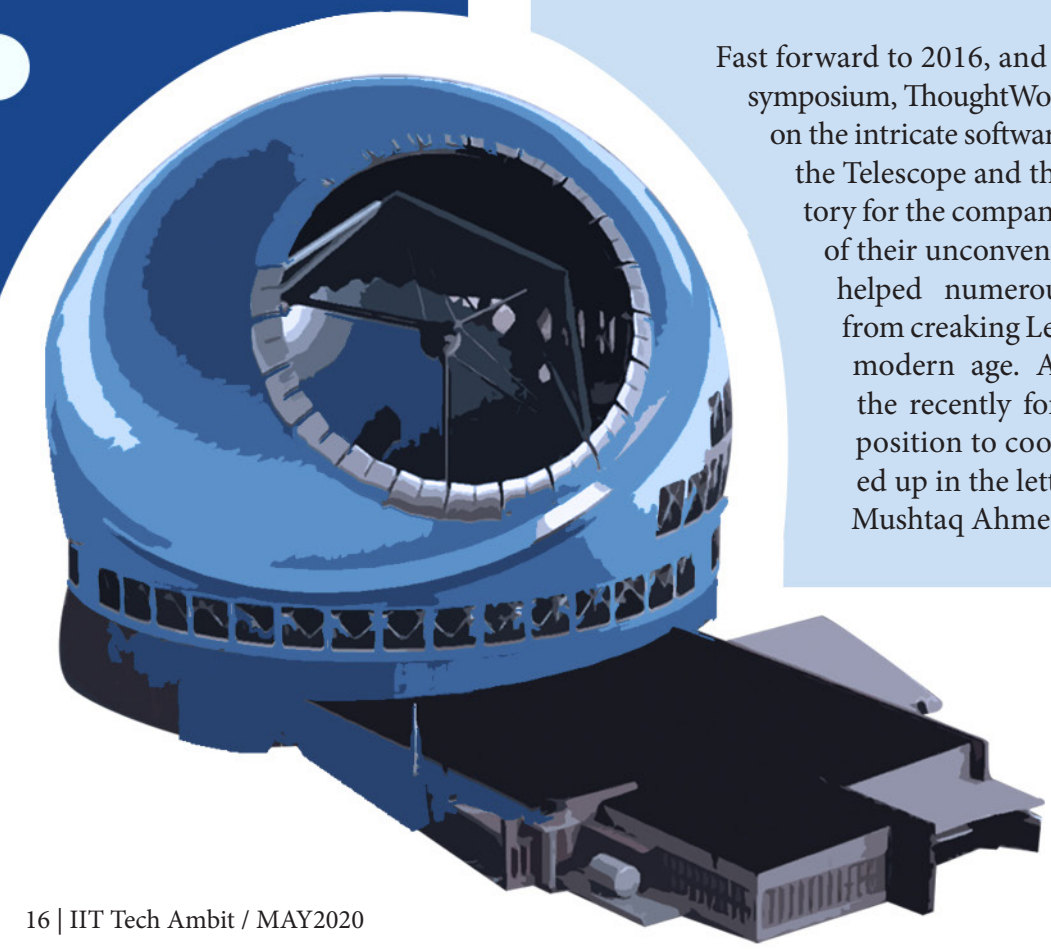
492 segments of reflective glass pieced together to form on giant primary mirror

RESOLUTION

12 times sharper than that of Hubble Space Telescope

TOTAL COLLECTING AREA

655 sq. m



The Pitch

ThoughtWorks' initiative, called Engineering for Research, or E4R, rolled along to its Pune offices, where Mr Ahmed is based, coinciding with developments occurring a little further away in Pasadena. The Thirty Meter Telescope project wanted a new kind of future-proof telescope - one capable of running for several decades, something almost inconceivable at a 21st-century rate of technological progress. A TMT executive, on the lookout for new technologies, attended a symposium on Scala, that ThoughtWorks happened to be presenting at.

Concurrently, scientists across India were gearing up for a new era - one of India's involvement as a critical partner in global science, preparing to take the lead in a changing world. At the Indian Institute of Astrophysics (IIA) in Bangalore in particular, the TMT was at the forefront of everyone's minds.

Global science projects are expensive; projects on space, even more so. Many developed economies, facing flagging growth rates and a populace highly resistant to a change in their standard of living, have begun disinvesting in science.

Conceptualised way back in 2000, progress began picking up only after India and China joined as observer states in 2010. Two years later after talks among a consortium including the governments of the United States, Canada, Japan and China, India came to the forefront of the project, pledging along with the Chinese to fund the entire construction costs of over $1.4 billion. The ITCC - India-TMT Coordination Centre - was set up with IIA Bangalore and IUCAA in Pune, to coordinate with vendors for the ludicrous amounts of hardware and software required.

Fast forward to 2016, and after the chance meeting at the symposium, ThoughtWorks submitted a Proof of Concept on the intricate software that would be necessary to run the Telescope and the observatory. Uncharted territory for the company, but they pitched the strengths of their unconventional digital solutions that had helped numerous industry clients transition from creaking Legacy systems to operating in the modern age. A contract soon followed, and the recently formed ITCC was in the perfect position to coordinate. The assignment landed up in the letterbox of ThoughtWorks Pune. Mushtaq Ahmed was working on telescopes.

The Telescope

The Thirty Meter Telescope project is ambitious. The 'thirty-meter' in the name refers to its diameter - something that would make it the largest optical reflecting telescope in the world by some distance. The current largest in the world is the LBT (Large Binocular Telescope) in Arizona, with an effective aperture of 11.9 m.

It is designed to operate in the near-ultraviolet to mid-infrared region (0.31 to 28 μm wavelengths) (that is, the light waves you can see with your eyes, but on steroids). Big telescope, big potential for future discoveries - it will play a huge role in understanding star and planet formation and the large scale structure of the universe as we know it. Did we mention black holes? It will help detect and investigate the gargantuan black holes at the centre of distant galaxies, as well as the one at the centre of the Milky Way.

The problem is that the technology to build a single reflecting mirror larger than 8.4 metres doesn't exist - it would be too difficult to fabricate. The ingenuity is in using 492 smaller hexagonal segments of 1.4 m each. The complexity is in making all these segments work together without room for an error - the smallest calibration mistake would result in an erroneous measurement and the loss of hours of data and dollars.

That's not all - integrated is also a new Multi-Conjugate Adaptive Optics (MCAO) system that will measure atmospheric turbulence. Based on these measurements, a pair of deformable mirrors would adjust many times per second to correct optical distortions caused by the turbulence.

Given this, it's no surprise the software needed to help the TMT function is as sophisticated as the hardware itself.

The Software

In October of 2019, it was revealed that the Common Software (CSW) for the telescope, developed by ThoughtWorks Pune, had passed the pre-shipment review stage. I reached out to Mr Ahmed, Tech Lead of the TMT project to find out more. I was directed to speak to two of the women at the forefront of this project: Chhaya Yadav, Project Manager (delivery) and Poorva Gokhale, a senior engineer on the team.

"There are 4 main packages that the TMT needs:

1. the CSW that is the communications backbone, connecting all 500 components;

2. the Executive Software, the frontend that provides the UI and functionality for operational users in the observatory to interact with;

3. the Data Management System to handle the storage, retrieval, collection and archival of the data;

4. the Embedded systems.

ThoughtWorks has been awarded the contracts for the first 3, and that's what we are working on", Chhaya explains, in an interview.

Before delving into the specifics of the Software Architecture, I find out a little more about why the software development process is so important, and what makes it difficult - and interesting. Two key factors:

Ms. Chhaya says, "Most of our clients require software for a particular use case over a duration of say 6 months - for an application like this, it would be more like 10 years. Not only that but since the telescope is going to run for 40-50 years, the software we provide must be able to adapt accordingly". Technology in the 21st century has always been made obsolete faster than we imagine it will. Software like this needs to be able to plug and play with newer technology with minimal hassle.

Second is the fact that this client is one very different from the corporate houses the company frequents. "Working with scientists is not like with a typical client at all", she says. "The relationship feels more collaborative than transactional, and rather than giving us a prototype with vague design requirements, they are able to tell us exactly what they want".

Both these facets - more collaboration and longevity - lend themselves well to something ThoughtWorks helped pioneer: a process called the 'Agile Methodology". Based on an iterative method, something that's been around since the 1950s, the approach was crystallised by a manifesto written by 17 elite software developers at a Utah resort in 2001. In essence, it boils down to continuous integration of functions and ideas, rather than a strictly chronological dev cycle - development and testing are concurrent. The project is broken into smaller chunks and continuously delivered in short 2 week cycles. Thanks to the continuous feedback they receive from the scientists, Poorva and her team are able to integrate those changes into the overall program, without the flaw being uncovered only after a lengthy delivery process, only to go back to the drawing board for ver 2.0.

Poorva Gokhale sits down to explain to me- what software exactly does a telescope need? It helps to imagine the archi tecture as a layer of skin with 4 levels.

Level 0 : The outer layer is the observatory hardware itself; the sensors and instruments receiving the input from the Great Beyond of deep space

Level 1 : The Hardware Control Layer (HCD) - this consists of actuators that, you guessed it, control the hardware. Commands are given from sequencers to rotate instruments and control motion - this is how the 492 mirrors in the honeycomb are positioned with incredible precision. That's not all. The developers created a UI to view the state of the sequencer, as well as an HCD writer. An interesting requirement here: since the scientists on the ground are no programmers, a domain-specific language (DSL) was written, to interact with the machines that are part of their life's work.

Level 2 : Assembly Layer - before the mirrors can be moved wholesale, a lot of fine-tuning is required. This allows control over the assemblies of filters and gratings that make up the telescope.

Level 3 : Sequencing Layer - here's where things get complicated. This layer acts as the brain of the sequencers that provide sequential steps for the commands that are given to the actuators in the HCD layer.

Level 4 : Monitoring and Control - these are the applications that take in the input data and process it. These require several astronomy specific tools, including some by the ICRAR (International Centre for Radio Astronomy Research). Astro map is an R tool for generating sky projection maps for astronomical surveys; ProSpect works on star formation histories; Simspin on galaxy simulation.

The Future

While work has been progressing well, the TMT's future is far from rosy. Even before the COVID-19 pandemic, bound to introduce funding doubts into each of the member states, as they rush to deal with more pressing issues, the project ran into trouble regarding its proposed location. With the summit of the dormant volcano, Mauna Kea in Hawaii, considered the ideal location (it would make TMT the biggest and highest altitude telescope), native Hawaiians for whom it is a sacred site have come out in protest. Although a stalemate has been in place with the government since December, no construction material has reached the telescope site since July of 2019. The proposed launch date in 2027 is looking more and more unlikely.

Yet this project holds a lot of promise with regards to Indian involvement in global science. Ms. Chhaya spoke about the several outreach programs the Department of Science and Technology (DST) has been holding with industry partners. The DST along with the DAE (Department of Atomic Energy) has identified 7 Mega Science Projects for India to be involved in over the next decade. These include the TMT, CERN in Geneva as well as the SKA (Square Kilometer Array telescope, a project under the purview of ICRAR).

The success of this project is crucial for more than the functioning of the telescope alone - something that by itself holds huge potential for revolutionising our understanding of space. It could prove that academia and industry can be equal partners in tandem with the government. That they can bridge the gap and help mend each other's shortcomings - efficient industry practices applied to the scientific development process, for example. Something that Mr Ahmed's team is demonstrating can be done to create a symbiotic alliance with unlikely bedfellows, given a common goal.

While there may be setbacks along the way, the progress of science is gradual but inevitable. Perhaps the lull this pandemic has brought allows us time to reflect. On what is truly important, laying our differences aside, and learning how to work together to create projects and make discoveries the world has never seen before. India is in a position to truly take the lead, achieving our potential as a global scientific powerhouse. We're taking steps in the right direction, but feedback along the way to iterate and refine our approach, from a few unconventional sources, wouldn't hurt.

THE STARS ARE WAITING

Success story of TeamKART: Formula Bharat 2020

Shaurya Shrivastava

With a rather mediocre performance in last year's Formula Bharat, the importance of funding such an expensive project as Formula Student in IIT Kharagpur was in question. It was clear that the next competition could very well be the Team's last campaign. Amidst increasing pressure, the Team was allowed to participate in Formula Bharat 2020. As the team leader, Tushar Patle says, "We wanted to prove to the institute and the faculty and they were not wrong in trusting us and supporting us even after a mediocre performance last year. We had a simple goal. Make a car within a year and participate in all dynamic events. Our Team had not been able to achieve either of those in the last 4-5 years. Fulfilling these goals under pressure was challenging," Tushar, a third-year mechanical engineering undergrad, led a team of around 30 members, which comprised second and third-year students from various departments.

Formula Bharat is an annually held student engineering competition at the Kari Motor Speedway in Coimbatore, India and draws participation from several national teams across the country. TeamKART, the official Formula Student team of IIT Kharagpur is one of the many teams which participated in Formula Bharat 2020. This is their success story as they change from underdogs to front liners.

Before May 2019, the Team was successful in getting an initial design of the car ready and manufacturing of the cars was already in the works. The design phase was short and the Team had decided against taking risky challenges.

Instead, it was decided that the focus would be on simplicity and reliability. This resulted in some design changes from the last year's car, the K4. The K5, as it was named, didn't feature any aerodynamic devices and had some compromises on some other subsystems as well. The Team decided to remove electronic gear shifter and anti-roll bar in the K5 which was implemented on the K4. Instead, a new DAQ system was

planned. The Data Acquisition System, or DAQ as it is often abbreviated, was one of the highlights of the K5. In essence, there were a few sensors installed in the car and data from those sensors were stored for further analysis. The K5 also featured a custom-designed radiator and full carbon fibre bodyworks.

"I believe if you are doing something like competing, like motor racing, you either do well or forget it."

-Ayrton Senna
Former F1 driver

The Team completed the entire manufacturing of the car by the end of November. A little more than a month was left for testing and driver training. The drivers were naturally those members who had been an integral part of the Team for around three-four years now. Extensive practice sessions were held in the last few weeks of 2019 to test the limits of the car and the drivers. Vatsal Kapadia, a third-year mechanical engineering undergrad recalls, "It was tough, to work the entire night on the car and then to drive for more than 2 hours in the morning. We had to do an extensive workout to ensure we had sufficient fitness, and the testing phase was physically straining for us drivers ."

As the new year began, the team members returned to campus with immense self-belief on their efforts till then. The car had performed well in the testing phase, and the competition was less than 20 days away. "We were confident in our car. In the last few days before the competition, the team worked with enormous enthusiasm while preparing for transportation of the car to the venue. They knew they'd perform well," recalls Aastha Sharma, deputy team leader at TeamKART. The car was thentransported on 15th January 2020, to the event venue, the Kari Motor Speedway, at Coimbatore.

The competition began on January 21, 2020. Formula Bharat is a five-day event, comprising three 'static events' (Cost and Manufacturing, Business Plan, Design) where teams are judged on their design justification, business presentation and costing skills, and four 'dynamic events' (Acceleration, Skidpad, Autocross and Endurance & Efficiency) which test the performance of the car and student drivers on-track. For participating in the dynamic events, all teams must necessarily qualify the technical inspection where judges qualify the car as safe enough for the competition. The technical inspection comprises mechanical scrutiny and three tests- tilt, noise and brake.

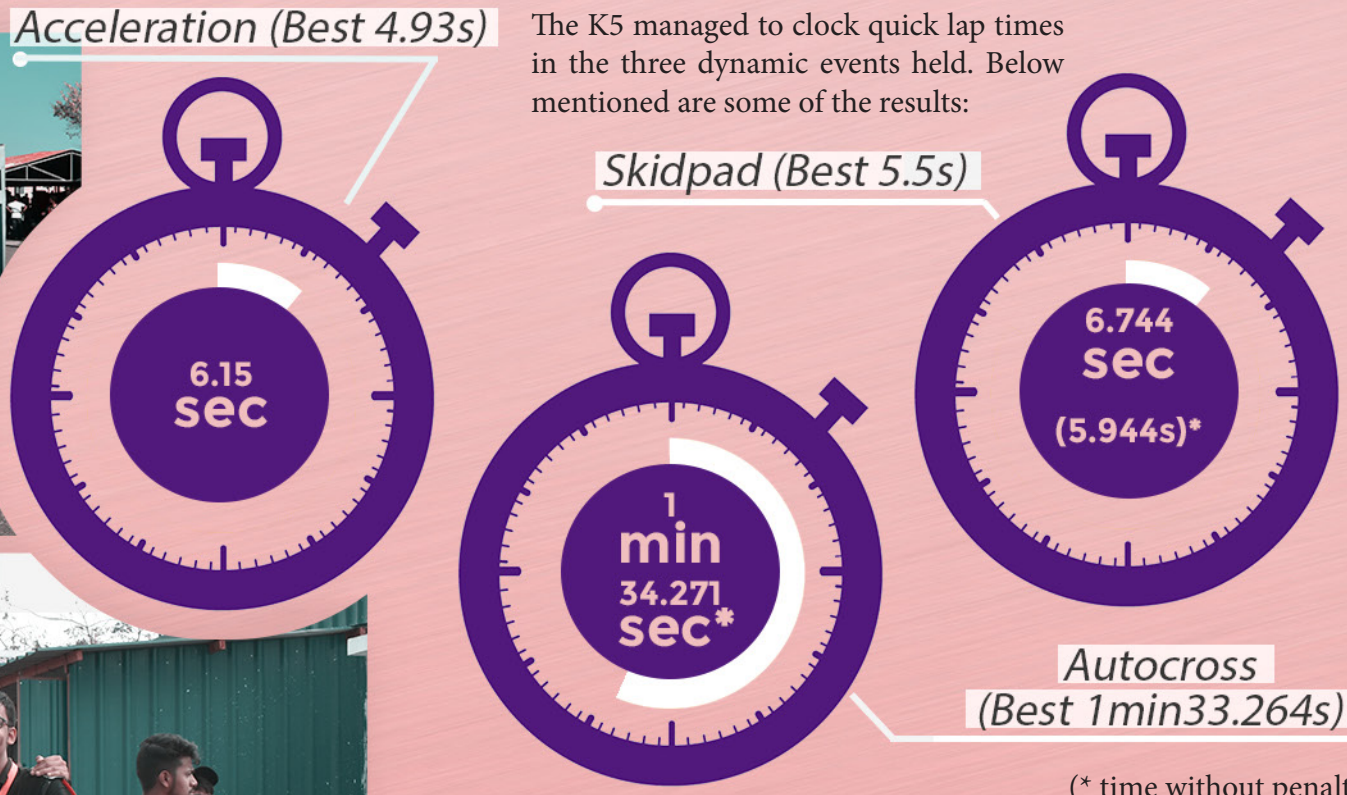
TeamKART was the second Team to clear the mechanical scrutiny, on Day 1 itself, which is no small feat considering there were more than 50 participating teams. On the very same day, the Team finished the tilt test as well. On day 2, the Team was busy in static events. TeamKART was placed 5th in the Design

event, which was an accomplishment in itself considering the various financial and time constraints the Team faced while designing. On day 3, the Team cleared the brake test, which meant that TeamKART had now qualified for the dynamic events, a first in many years for the Team. The team also managed to bag the first runners-up position in the Business Plan Presentation, which has been a forte for the TeamKART ever since it was bagged the same position in Formula Bharat 2017. The Team then took its car to the Dynamic events. A moment that was a dream come true for all the former team members, the alumni and the current members as well. This was the ambition they had worked for, the past one year and they were witnessing it.

Overall, the Team ended up with a brilliant 10th, a significant improvement over last year's dismal performance.

Pictures from the events held at Formula Bharat 2020

The K5 managed to clock quick lap times in the three dynamic events held. Below mentioned are some of the results:



(* time without penalty)

Overall, the Team ended up with a brilliant 10th, a significant improvement over last year's dismal performance. Throughout the competition, the Team interacted with other teams, observing and discussing the different design and manufacturing approaches they followed. This is perhaps the biggest takeaway in the Formula Student competitions across the globe- that all teams learn a lot from each other. The competition also provides the members with an opportunity to interact with the veterans of the motorsports community, like Pat Clarke and Claude Rouelle, who have judged various Formula Student competitions around the world.

TeamKART now aims to participate in Formula Bharat 2021, an attempt to continue its dramatic shift to the one car a year choice, which proved to be transformative for the Team. In fact, the Team has already started working on its next vehicle, the K6, which will be a big design upgrade with some significant changes. Formula Bharat 2020 will nonetheless be a milestone in the Team's history. The team is now deeply motivated to prove its mettle to everyone once again and continuously stand up to the high expectations now onwards, making the institute and the faculty proud.

In this journey, TeamKART would like to thank their faculty advisors, namely, Prof. D.K. Srivastava, Prof. S.K. Panda, Prof. Amiya Mohanty(current H.O.D. of the mechanical department and former faculty advisor), Prof C.S. Kumar and Prof. Atul Jain for their constant support and help throughout our preparation.

The State of Hyperloop

: Part 3

Pranav Krishnan

Hyperloop in the real world

Outside the competition and its contained excitement however, the real world hasn't gone anywhere. Hearing there would be an Indian Hyperloop team coming to California, Virgin Hyperloop One co-founder Josh Geigel invited the team over to their headquarters in LA. Both Avishkar and Hyperloop One are working on developing the same technologies – passive magnetic levitation and a linear induction motor – albeit at different scales, resulting in an enthusiastic discussion with hopes of collaboration

The real reason? Hyperloop One signed an 'agreement of intent' with the Maharashtra Government in February 2018 to build a hyperloop route between Pune and Mumbai, to the Navi Mumbai airport. In July 2019, the Government approved the plans and announced the DP World – Hyperloop One consortium as the original project proponent for the hyperloop project, announcing it as a public infrastructure project, and leading all parties to proclaim that India will be the site of the world's first hyperloop. The prospect sounds hugely enticing to the estimated 1.5 crore annual passengers travelling this route annually, several as a daily commute for work (the two cities are hubs for software companies, MNCs and industry, making up the heart of Maharashtra's economic powerhouse). Hyperloop One claims the 150 km journey that takes 3 hours today by road, will be shortened to just 13 minutes. The realm of science fiction, yes, but Hyperloop does not shy away from being exactly that.

A massive spanner in these works may have come in the form of the political tumult that hit Maharashtra following the State elections in October. Coalition partners, the Nationalist Congress Party (NCP) have demanded new Chief Minister Uddhav Thackeray scrap the project citing the expenditure and risk. A slew of infrastructure projects like the proposed bullet train from Mumbai to Ahmedabad and a new expressway has been put on hold by the new government, ostensibly to reprioritise govt. funds for farm loan waivers and cheap meals for the poor, among other initiatives.

Confusion in the minds of safety regulators - in particular, who the hell exactly would regulate a project that is neither a railway or road transport - led to delays, postponing work for after the elections. A worried Richard Branson himself,

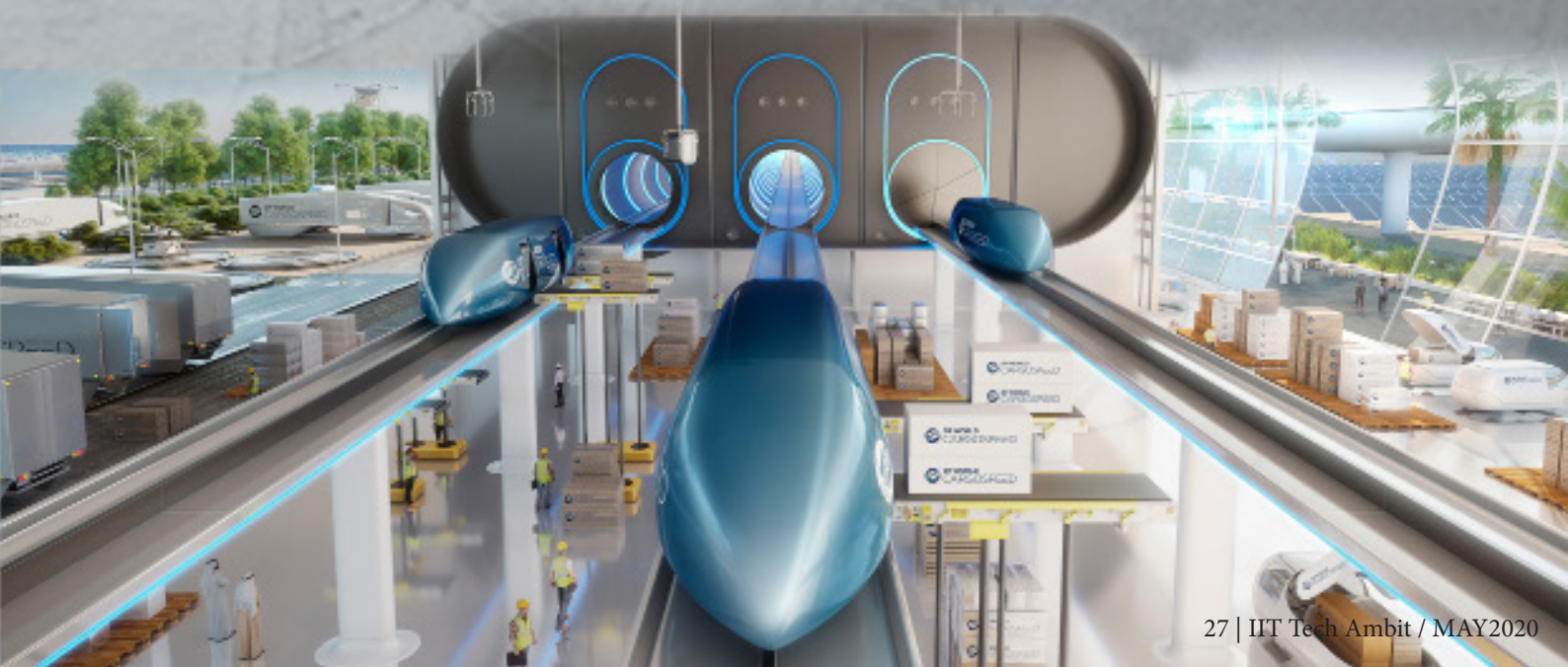
the evangelist granddaddy of the Virgin Group, hurriedly flew down to Mumbai in December to speak with the new Chief Minister, throwing a new Mumbai-London Virgin Atlantic flight into the mix. Unlike their partners, the Shiv Sena has been cautiously diplomatic about this project and others, stating only that it recognised the infrastructure important to the state and that appropriate processes would be put into place. Even if the project were to get the green light though, the road ahead is uncertain given it being notoriously difficult for land acquisition, tariffs on imports and various other barriers that have historically existed in India to large foreign infrastructure projects. Geigel wanted the IITM team's inputs on the current on-ground scenario, possibly to allay concerns that the government bodies involved were not telling them all they needed to know, said Aditya.

Team Avishkar's achievement comes well-timed with the announcement of the Mumbai-Pune hyperloop, and indeed, a short route of this kind of profile is the most likely to succeed. Being in the same state, over a relatively pliant terrain, the conditions are positive. Connecting two highly urbanised cities with significant volumes of upper-middle-class commuters to be able to recoup initial investment is also crucial - approximately 75 million passengers journey between Mumbai and Pune annually, which is projected to leap to 130 million by 2026.

A clear idea about the kind of money that will have to be pumped in to make this happen isn't forthcoming from either party at the moment, but DP World, who is also a major ports and logistics operator in India, is set to invest $500 million to complete phase 1 of the project. Phase 1 involves building an 11.8 km demonstration track by 2023, proving that the concept is viable for passenger operations. An expensive experiment indeed, and one with sharp criticism. While in theory, energy costs of the hyperloop would be close to nil, because of the solar panels built on the tube, projected estimates for the project place the total cost at least $10 billion. Critics including former Maharashtra Chief Minister Prithviraj Chavan have called the project a case of misplaced priorities, especially in Pune where some areas have booming construction projects coming up, without taking into proper account basic utilities like water and electricity.

Time will tell whether Hyperloop truly leaps into our civilisation, bringing to reality the blueprints of a technology dreamed up by futurists centuries ago. We seem well poised to do so, but equal doubts about the implementation of such a capital-intensive model of transportation remain. Will those who don't board in time be left behind? Or will we rue having pumped all our money and time into hyperloop's shiny tubes, when there were more pressing problems at hand?

It's the perennial question of 'Avishkar' – of the invention.



AgRobots: A glimpse into Futuristic Farming

Jasmine Jerry

Summary:

Dr Girish Chowdhary is a professor of Agricultural Engineering at the University of Illinois, an expert in autonomous unmanned aircraft and currently the Chief Technology Officer and Co-Founder at EarthSense, an agri-tech startup. We couldn't have got a better person than him to moot the role of robots on farms. He also went on to discuss the present state of agriculture in the USA juxtaposed with Indian farms, how automation is helping American farms and why India needs a different scale of farm automation that might help it in its growing agricultural demands.

Farms located on opposite sides of the globe:

There are nearly 2 million farms in the USA, and the number is dwindling. Some states have land areas averaging more than 2000 acres in size. The United States has the second most arable land in the world, the first being India, followed by Russia, China & Brazil. At the same time, as the number of farms in the United States decrease, the average size of farms increases. In the '50s and '60s, more than half the American population was involved in farming. Soon, there was a rapid decline in the farm population, and many farmers sold their land and moved to urban areas. Other farmers acquired these lands, and thus field sizes grew organically. Farm machinery became more powerful. The people that continued in agriculture became adept and experienced. Only 1% of the population is involved in agriculture in the present day.

Unlike the US, in India, farms are smaller, ranging between 10 and 400 acres. Another challenge India faces is land ownership. In India, owning land is remotely connected to one's ancestry and prestige. There's an expectation for the property to pay off better, later. Also, the regulations regarding the sale of agricultural land are intricate and if existing, are lax. To get back sold land is even more elaborate. The obstacles Indian farmers faced around 20 to 30 years ago were associated with irrigation. Today, the biggest problem is the lack of sufficient labourers. When a team of scientists went to interact with the local agriculturists in Dharwad district of Karnataka, India, they reported that farmers were lacking low-cost labour for various field tasks. Weeding an acre-sized field with 8 to 10 people takes an entire day and costs around 3000 INR, spraying insecticide costs about the same amount. The farmers incur significant losses.

The caveat is that this is only in variable costs, that is, not accounting for the fixed costs of tractor ownership. Since the labor has to be done manually, those costs do not matter here in India, but in the US, the mechanization is what brings costs down.

> "Essentially, farmers here spend more money to prepare their fields and crops as compared to the US which is very surprising. The way out of this messy situation is using automation, potentially with robots."

Robotics Lab to Agri-Startup "EarthSense": The foundations

Dr Girish Chowdhary is an aerospace engineer and Professor at the Distributed Autonomous Systems Lab, University of Illinois at Urbana-Champaign. He graduated with a PhD in a strong aerospace program and worked in the aero-industry for a while. But his motivation was to take on the major challenges the agriculture industry faces today globally.

The enormous farm sizes in America are split into 80-acre parcels, spread out around 200 - 300 miles and controlled by three or four people. Thus, large scale automation is required, and profit is made by scaling up their field sizes. This farming system is not sustainable- it uses excessive chemicals, alters the soil and pushes farmers into growing only specific types of crops. Agriculture then becomes profitable only on a large scale. Dr Chowdhary and his team noticed this gap that existed between big machinery and human labour which could be solved using modern technology. The diminishing farm

workforce needed an automated solution. This led to Prof Chowdhary and Chinmay Soman to co-found the robotics startup, Earthsense, Inc. at Urbana, Illinois.

His team's initial plans were to use groups of unmanned aerial robots to solve the problems in the agricultural fields like pest and disease control. But soon, they realised they had to reach the plant roots and get under the vegetation canopy, as a wide variety of crops required monitoring for weeding and spraying at the stalk and leaf levels. Another challenge was the endurance of these machines. Multirotors have a battery life ranging from a few minutes to half an hour. They wouldn't last long enough for covering large agriculture fields that required a significant period of monitoring without having battery spares and recharging breaks. Thus, they decided on using wheeled ground robots for smaller farms and closer crop management.

EarthSense proposed a new mechanism—the idea of having decentralised small ground robots for farms—to fill that void. The goal was to make the simplest of these wheeled robots. They developed ultra-compact, autonomous, teachable robots for crop breeders, scientists, and growers.

Their first robot—TerraSentia—TerraSentia uses a combination of sensors—including visual cameras, LIDAR, GPS, and other on-board sensors—to autonomously collect data on traits for plant health, physiology, and stress response. TerraSentia's unique dataset delivers high-value under-canopy plant traits that improve the quantity, accuracy, cost, and speed of in-field plant trait data collection. Using machine vision and machine learning based analytics to seamlessly convert field data to specific, actionable information about plant-traits, unlike other technologies, TerraSentia aims to be a big player for crop breeders, plant protection products developers, crop scientists, and field agronomists. These were also presented to the farmers at Dharwad. The farmers were very excited about the small robots and welcomed the new technology.

Future of Agriculture in India

The problems of Labour, excessive chemicals and sustainability

For the Indian farm scenario, these small robot tractors fit perfectly. Farming in India is still stigmatised; not many actively take it up as a career option as the risks are high. On the other hand, innovations in food technology are the need of the hour. The farm workforce is reducing. Farming may not be the same anymore: The future of agriculture needs robotic automation. The challenge here is the right way to automate. Agriculture has a wide variety of tasks involving

> "People get excited when their problems get solved. These robots are being designed to solve their labour problem."

"The present situation is not sustainable, our future generations won't have the same fields and food might taste different than what we have. What we take for granted today may no longer remain the same. With mega farms and excessive chemical-laden agriculture, we are losing nutrition and taste. The soil is getting degraded. Something needs to be done", Prof Girish informed us.

human-human, human-machine and machine-machine interactions. Here, the problem of accurately programming how these robots would interact with each other and humans arise. Solving this is key to upgrading Indian agriculture.

We need to start small and scale-up subsequently. As time progresses, we would require many robots in big fields, collaborating with each other and the human operators. The final step would be a complete system of small robot tractors along with aerial robots and maintenance robots working together all connected with the cloud. This is what EarthSense aspires to create. The need is to build a community of smart young people and motivate them for improving farming. The level of internet connectivity is relatively strong even in rural areas, and data is accessible to many, making it easier to implement these systems.

Required Regulations:

Unlike self-driving cars which are too far out and regulations to be taken care of, AgRobots are much closer to being fully deployed as small robots soon. Regulations are yet to be developed as these are small robots on private land. It's a suitable environment now for future developers to innovate and ideate to come up with the best prototypes.

Should agriculture education incorporate robotics and related technology? Dr Chowdhary feels it should occur in an organic way, not imposed on students by making them mandatory. There must be elective subjects and optional classes. Various student interest groups can arise, motivated to work on these issues. Food production is of utmost importance, and we need more workforce developing AgTech.

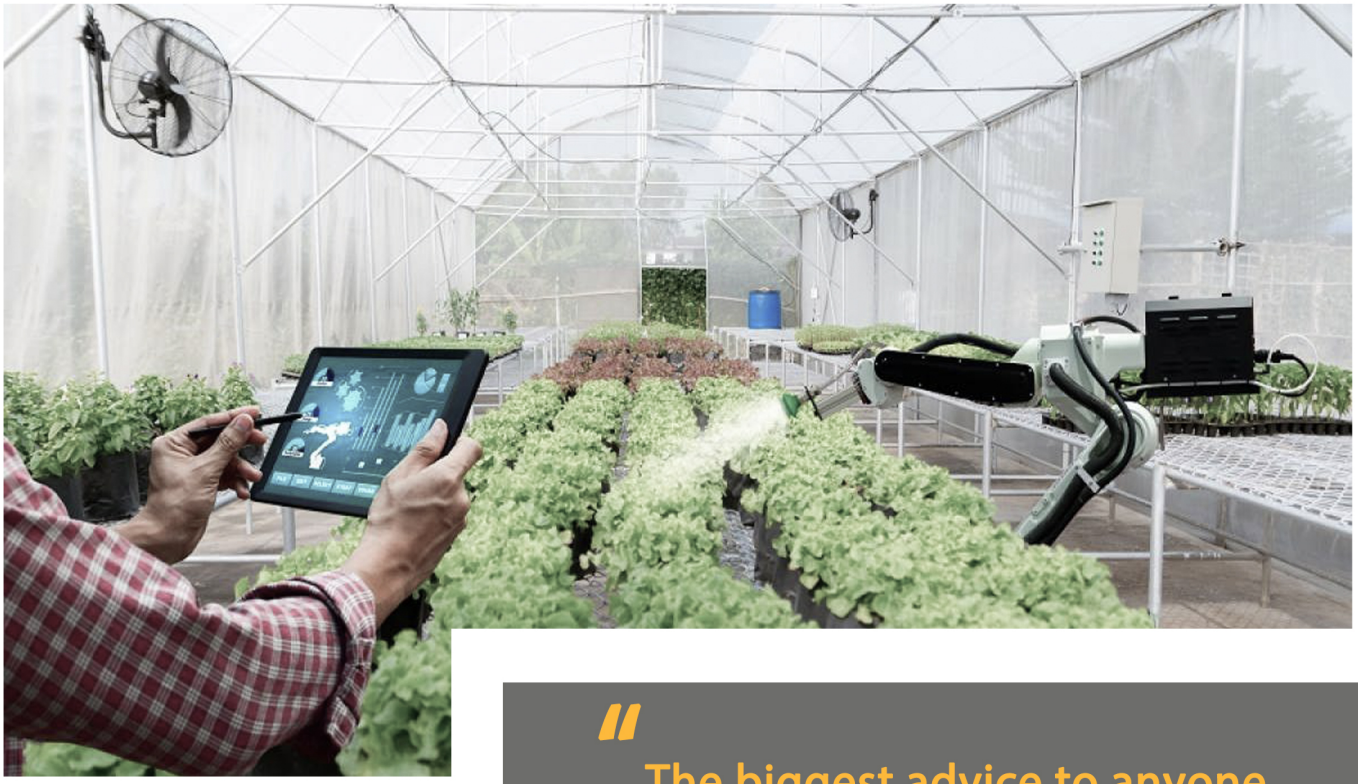
We need to raise more awareness and get the smartest people involved in solving these problems. There are a lot of skills required in these fields, but on learning them, the utility is not limited to agricultural farms. EarthSense would also tie-up with technological institutes, agricultural schools and learning centres to produce local talent.

Advice for Agro-Tech Start-ups

New ideas come by interacting and thinking critically about technology, its application, and the end-user. How the end-user will use the technology should drive the problem. An excellent product-market fit is a key to success. Agricultural technology allows innovations at multiple levels starting from seed to the harvested crop. Having a functional relevance--developing technology that will be relevant to someone else some time in the near future--should be kept in mind. Technology development and technology adoption have disparity and should be the guiding factor for a start-up.

Motivational speaker and life coach Steve Black says that before we spend two whole years of our life building a product, trying to develop something and then aim to sell it, we must start with the customer. We must go with a hypothesis, a solution to do a particular job and ask the customer. Then, listen to what the customer is saying. Is he/she excited? Is there any suggestion? Use of another technique, perhaps? Use this as a pivot to find a match of what they want that agrees with what you can do. Once you find the match, the path from there is a smooth one.

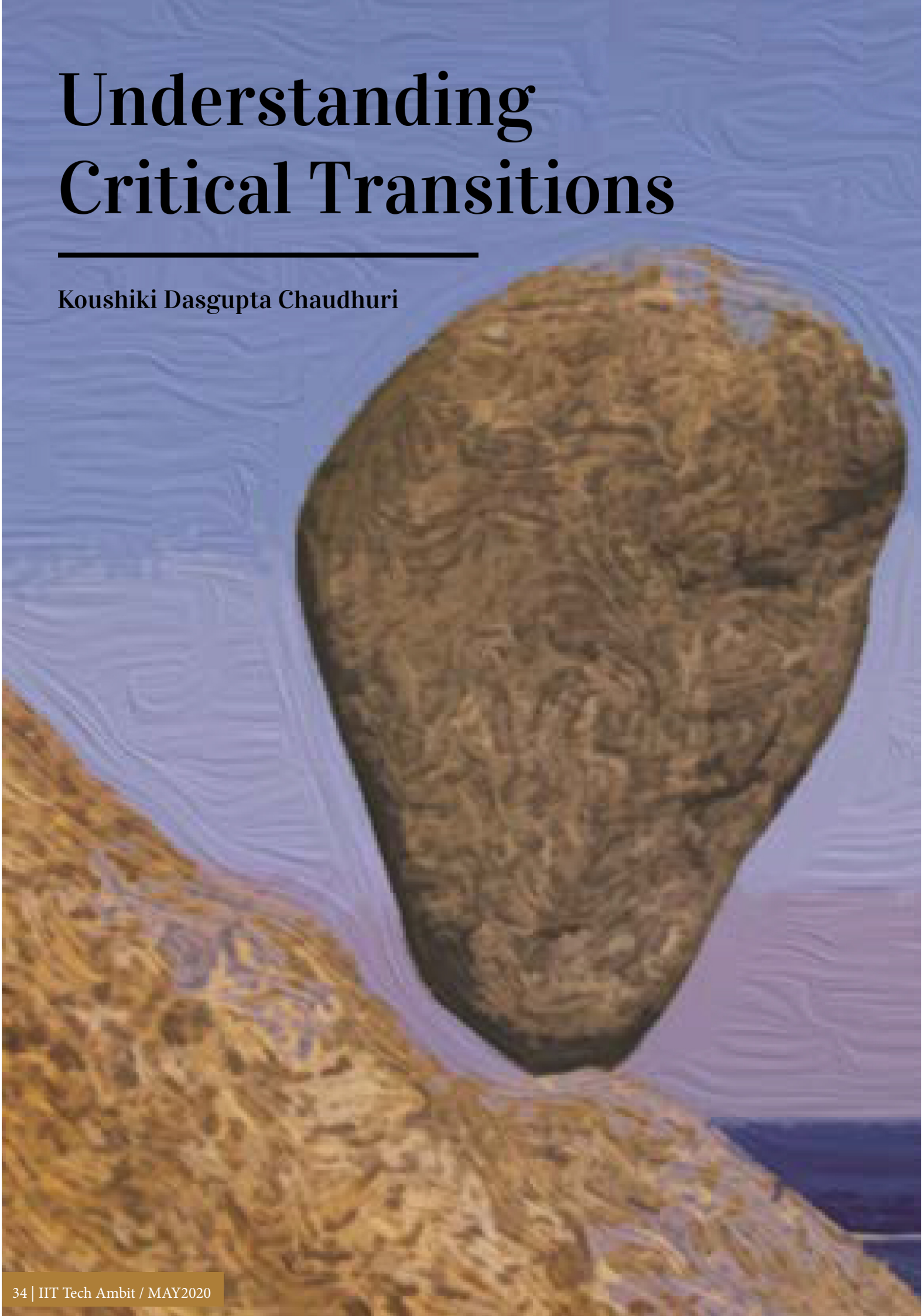
> "A utopian situation could be robots running farms for almost no labour charges. This might sound like science fiction from Iain M Banks' stories! We need to look for feasible solutions."



"The biggest advice to anyone who wants to work on a start-up is to understand the problem they want to solve by asking questions to future customers and stakeholders. This is essential to figure out a good product-market fit. Go out and find what people are looking for, not what you can build already."

Understanding Critical Transitions

Koushiki Dasgupta Chaudhuri



As Shelley declared in Frankenstein, "Nothing is so painful to the human mind as a great and sudden change." Yet we, on our high horses as masters of the world, often ignore the tell-tale signs of impending change nature keeps leaving around us. And end up waking one day wondering what got us here, so far from where we started

Take, for example, desertification. Many lines of evidence suggest that desertified land was once filled with a lush green cover. Indiscriminate cutting of trees and increasing wind and water runoff eroded fertile remains of the topsoil, making the ground too harsh to be recolonised by perennial seedlings. Though the factors of change might have been at work for hundreds of years, the change, when it happened, was sudden and abrupt compared to the centuries of stagnation that preceded it. That being the way of change, it becomes imperative that we learn to understand and predict some of these changes happening around us in order to embrace them better or even work on preventing unwanted ones. It was only around 2009 that Marten Scheffer, a Dutch ecologist and mathematical biologist, came out with one of the first papers on critical transitions, which seeks to explain these changes. Hence started a flurry of research on this extremely interesting and useful field, which can have applications as varied as preventing large-scale ecological transitions like desertification or predicting the exact moment when a pathogen outbreak will occur in a threatened system.

A majority of natural systems have multiple states of equilibria at any given point. When a drastic change occurs from one state to a contrasting one abruptly due to a small change in a parameter, it is called a critical transition. Critical transitions are of great interest not only in natural systems in ecology but also in systems in engineering, medicine, finance, economics etc. e drastic consequences.

Such studies are important because switches to a contrasting alternative stable state can often have drastic consequences. For example, the loss of transparency and vegetation observed in shallow lakes subject to human-induced eutrophication. As the nutrient concentration passes a critical threshold, the lake shifts abruptly from clear to turbid. In epidemiology, critical transitions are of relevance to the emergence of new pathogens and the re-emergence of old ones. An intervention may cause the host-pathogen trajectory to cross a critical transition where pathogen prevalence drops to apparent eradication, the robustness of which is strongly determined by the structure of the transition. In financial markets, these critical points are connected to systemic risks, which have led to a financial crisis in the past. Critical transitions are present in a variety of engineering systems such as an aeroelastic model exposed to gusts. Hence it is pretty evident that the study of critical transitions is important not only to prevent unwanted transitions but also to have a greater understanding of the changes that occur around us.

Dynamically, critical transitions are represented by bifurcations, that is, qualitative changes in Spatio-temporal behaviour caused by small changes in parameters. There are different kinds of bifurcations, called by different names in mathematics and physics, which give rise to critical transitions in varied systems. Work on critical transitions has two main avenues- working on a temporal scale and a spatial scale. So far, most of the work has focused on studying early-warning signals, which are certain trends in systemic properties that appear as a tipping point(point of critical transition) is approached. These early-warning signals are mostly an increase in auto-correlation, an increase in variance and a slower recovery from perturbations. The phenomenon of critical slowing down(systems take an increasingly longer time to recover from perturbations as a bifurcation is approached) has been extensively used to study other early-warning signals which can predict an impending transition. Cases studied are as varied as systems in ecology such as global climate-carbon cycle models which predict loss of soil carbon under global warming to studying super-infection in malaria transmission models or using bifurcation-based sensing approaches in piezoelectric impedance-based structural health monitoring.

Early-warning signals have been particularly useful in the field of finance to predict critical transitions such as a stock market collapse. In a topology data analysis based method, time-series of multiple stock prices have been used to build time-dependent correlation networks, which exhibit topological structures. The persistent homology associated with these structures has been used to track the changes in topology when approaching a critical transition. This method has been successfully applied in a case study to investigate a portfolio of stocks during a period prior to the US financial crisis of 2007-2008 and show the presence of early signs of the critical transition.

In living systems, model-less forecasting methods have been used to forecast an impending transition, like in a yeast population which exhibits a critical transition as the environment deteriorates. This method uses the phenomenon of critical slowing down to find a relation between recovery rates of the system as it recovers from perturbations to distance in parameter space to the tipping point. By measuring time-series of the system as it recovers from perturbations at two parameter values in the pre-bifurcation regime, it has been able to predict the parameter value (dilution factor here) at which bifurcation will occur, that is, yeast population will become extinct. The method has been justified by experimental data.

However, most of the work done so far is retrospective in nature, that is, it talks about early-warning signals and their trends only after a critical transition is breached and we have a wholesome understanding of the system dynamics. To prevent unwanted transitions from occurring, we need to be able to predict them beforehand, even before entering the bifurcation regime, which is what current research focuses on. For this purpose, several model-less approaches have been proposed, each with their individual drawbacks. Further avenues of research lie in finding a unified method that works for real data under stochastic external noise and not just controlled simulated experiments. They should then be extended to the spatial scale so that we can ultimately start working on sustainable management practices in ecosystems, for example, to prevent catastrophic shifts and focus on maintaining resilience.

Such studies can lead to tremendous booms in the business market if we are able to accurately forecast stock market trends. Relevant technologies can be built for sustainable management of ecosystems which focus on reducing the loss of resilience. They are already of relevance to a variety of engineering systems. Epidemiological work can branch out towards malaria and cancer research. The most interesting aspect about this field is that the same underlying principles can be applied to a variety of disciplines, which, of course, is the entire point of inter-disciplinary science. Change might be the only constant but controlling and mastering these changes may effectively make us masters of our own destiny.

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