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Reimagining Research

Dr. Gautam Shroff

Research plays a critical part in TCS' business. Being close to market leaders across industries offers TCS Research a ringside view of new technology adoption and the problems that need to be solved in the process. Interacting with customers, academics and technologists for the past three decades has been an immense source of learning for me personally. I would like to share some thoughts here on what I see ahead of us. And how we at TCS Research are reorienting ourselves to keep pace with these trends.

Three Game Changers

The pace of technology evolution is set to increase like never before. I see three important drivers:

- There is a growing availability of data about virtually everything, from people to machines to the environment. Everything that can be measured, tracked, and stored, will be, as communications and storage becomes cheap and ubiquitous.

- Super-linear improvements in the capabilities of Artificial Intelligence (AI) techniques to mimic, and in many cases, surpass human abilities, in tasks normally associated with requiring human involvement:

  i. Tasks requiring perception and understanding, e.g. recognizing objects, faces and text from images and video, transcribing voice to text, summarizing documents, and translating one natural language to another.

  ii. Prediction tasks, e.g., detecting as well as forecasting a machine failing, or a patient having an adverse reaction or even a hospital re-admission.

  iii. Prescriptive tasks, e.g., making complex decisions, such as which move to make next in a game, or which train to schedule on which track; tasks for which optimal solutions are, in principle, mathematically computable, but in practice, computationally intractable, but which humans manage quite well using experience and.

  iv. Participative tasks, e.g., physical machines (robots) operating autonomously in the realworld, such as self-driving cars, or flexible industrial robots that can be "taught" new jobs or even learn by watching humans, rather than being programmed.

- The movement of the traditional brick-and-mortar economy as well as governments towards integrating AI techniques into their IT systems. This will be the most impactful development as these are organizations responsible for 90% of the global GDP. They will better exploit their internal and external data so as to drive fundamental changes to their business models.

AI Meets the Brick and Mortar Economy

We are already seeing signs of this. Banks are seeking to go beyond being mere accountants of money and facilitators of payments. They exploit the data they are privy to information such as "who pays whom for what" to assist merchants in their advertising and pricing strategies.

Insurance is moving from provisioning to prevention; examples include mobile apps that track the driving behavior of customers and reward those that drive more safely as well as health monitors to

encourage fitter and healthier lifestyles. Not just autonomous vehicle makers, but all car manufacturers are using data from the hundreds of sensors that populate each modern vehicle to better predict failures and prevent costly recalls. Similar trends are observed for telecom operators, utility companies, retail chains, hospitals, and even governments. At the heart of each of these applications lies the intelligent analysis of data and convergence as traditional IT systems become AI-driven.

AI in the Fight against COVID 19

AI was leveraged in many ways to fight the COVID-19 pandemic of 2020. AI speeded up pharma research towards designing new molecules that may well fight the virus. It helped epidemiologists predict how the pandemic would spread and thereby helped state department manage lockdowns with as much efficacy as possible. In a time when most everyday actions were performed online (work, recreation, baking, shopping etc) AI played a critical role in ensuring safety in networks.

The Horizon-III Stars

What might transpire in 20 years or even 10, is difficult to predict in a frequently disrupted field like information technology. Here are some possibilities.

Quantum computing will likely be commercially viable. For this, the world has to re-invent its communications infrastructure to ensure security, as traditional encryption techniques have become easily breakable.

Machine-learning will become significantly more efficient enabling the processing of vast amounts of data in real-time. This can be either via quantum or even DNA-based computing, or the development of neuro-morphic chips based on the next generation of deep neural networks.

The biggest disruption will be at another grand convergence: better robots and cheap energy.

Robots might achieve human level dexterity. Energy-surplus may be achieved via solar, nuclear, or other means. This can drive the cost of production for virtually any goods to near zero; for with free energy, AI, and robots, we could both design and produce new materials including food, and manufacture whatever is needed for human consumption, at minimal cost. The economic impacts of a truly "free" economy are already being debated, albeit only as a matter of speculation at present.

Whatever might be the mechanism by which wealth is created and distributed in such an economy, one thing seems clear to me at least: leisure and digital entertainment will increase.

Advertising, in whatever avatar, will be needed. Data about consumers, consumption, and needs will increasingly drive the creation of new materials and products as well as manage their delivery and consumption for the purpose that we humans have always striven for—ever increasing prosperity and well-being in whatever sense society might choose to measure.

TCS Research will have to embrace these developments and help customers make smooth transitions at every evolution.

Research Paradigms at TCS

The Tatas believe in delivering the benefits of science to the common man. This vision led to Research as a separate activity in a dedicated facility in TCS with the establishment of TRDDC in 1981, the Tata Research Design and Development Centre in Pune. Chairman F.C. Kohli and Director E.C Subba Rao attracted globally renowned researchers to the center. At this time, coding was artisanal. At TRDDC, Professor K.V Nori in particular worked on paradigms that would move computer science towards software engineering; from theory to repeatable, scalable, and sustainable practice. We focused on model-driven development and object-oriented programming. We built dictionaries, compilers, translators, and program analysis tools. This resulted in some pioneering products both for software automation (MasterCraft)TM and TCS Embedded Code Analyzer), Industry (BaNCS), and Society (Swach). The most important thing we learnt at TRDDC, however, was to look at a real world problem and abstract the issues to solve a large set of problems they indicated.

As our Research moved from TRDDC to global centers, we adopted a portfolio model in 2006, where we looked at research in the short- and long-term. This helped us deliver a number of solutions, platforms

and even lines of business (Ignio)TM, while progressing with long-term research. Many of these stories have been published in our earlier book Research by Design, our website www.tcs.com/research in our research reports. We also published a significant number of papers and filed for patents.

Now we are at another inflection point. If technology evolves faster, applied research must also speed up. As we do not want to stop looking at big research problems ambitiously and at depth, we have started industry-focused innovation units within the business, so as to keep one arm of research delivering innovation continuously for our customers. These will draw on the greater scientific rigor and long-term exploration taken up by the central research team. From the central team's explorations, we have initiated a formal mainstreaming of research as future-facing business lines.

A People Culture in Research

From its inception at TRDDC when professors from CMU did seminal work, the aim has always been to attract talented researchers and offer them a distinct career path. The research community in TCS has grown with many shining stars. We have rich connects with academia around the world providing a channel for exchange of ideas with some of the best minds in the world. Mentoring of junior researchers is something we take seriously. The research advisory board meets with researchers at regular intervals, reviewing work, and also providing outsidein perspectives. We encourage researchers to keep their thirst for knowledge alive by offering sabbatical opportunities. We insist that they learn and be esteemed by peers: publications and patents are critical metrics for TCS researchers. A vital factor to the success of our research is that researchers are well respected by the business. TCS Research leaders have direct access to the CxOs in the company.

Current Research in TCS, with an AI Lift

While today we are organized into eleven research areas, elements of AI run through each of these: the original Software Systems and Services group that created model-driven software engineering is now focusing on AI-driven program synthesis and meta-model based AI systems. Physical Sciences,
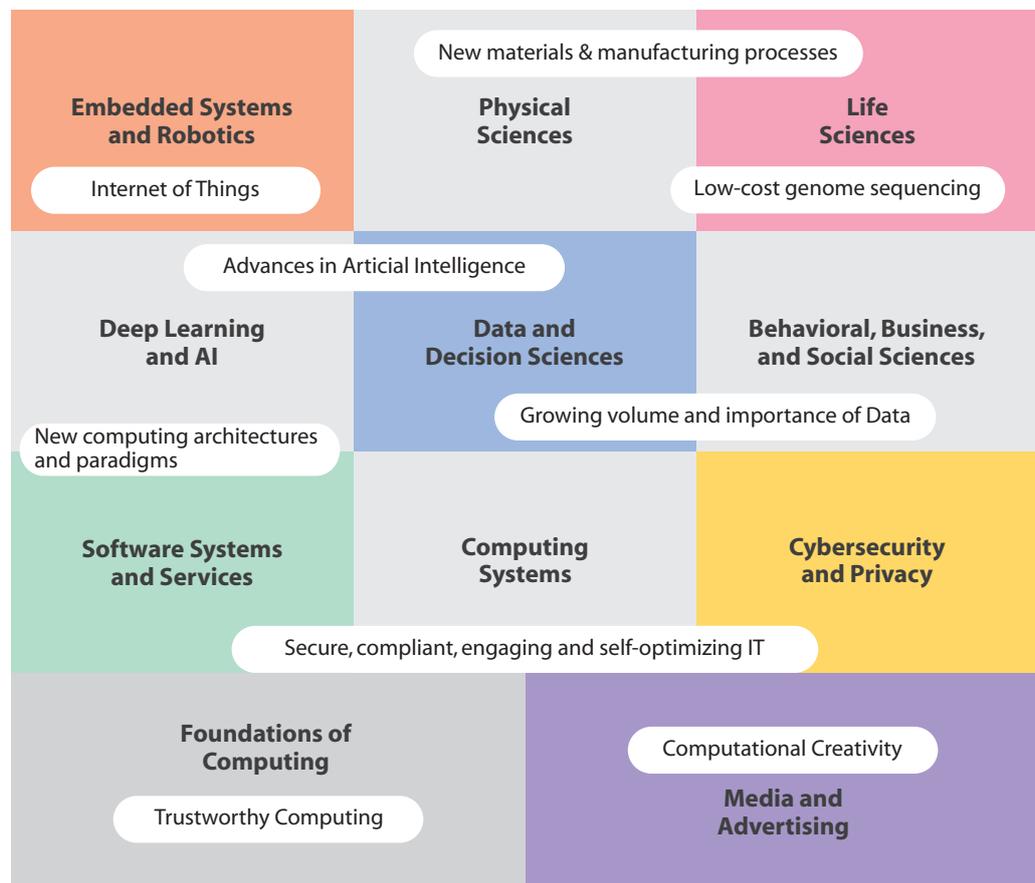
with its expertise in computational materials engineering, has developed research programs for IoT Analytics using AI, and is discovering new materials via data-driven techniques.

Life Sciences, with its focus on genomics and meta-genomics, leverages machine-learning for both personalized medicine as well as new explorations in synthetic biology. Embedded Systems and Robotics is developing a business in intelligent and flexible robotics for Industry 4.0 applications as well as for emerging connected healthcare ecosystems. The Cybersecurity research area is addressing the many privacy concerns engendered by AI via its tools for end-user control and content that are finding rapid traction given the growing global concerns in this arena. To deal

with the growing importance of data, both the Data and Decision Sciences as well as the Deep Learning and AI research areas deal with cutting-edge research such as applying reinforcement learning to real-world optimization problems, or applying and enhancing the latest deep-learning techniques for sensor analytics, text, and image processing. With data about individuals today being so prevalent and rich, the Behavioral Business and Social Sciences research is, among other things, attempting to study collections of people much as physicists study collections of molecules, as well as mechanisms for technology to add to entertainment and the inevitable advertising that goes with it. Last but not least, software applications, AI or otherwise, need to be engineered for high performance and use the latest in computing technology, which is the focus of the Computing Systems research area, such as developing high-performance, deep-learning frameworks for e-commerce or keeping tabs on emerging trends such as quantum computing.

In this book, which is the sequel to the volume published in 2018, we highlight examples from TCS Research across two distinct themes, the industrialization of computing on the one hand, and the digitization of industry and society on the other. The former theme is organized into sections covering Data and Computing related topics, while the latter into sections on Industry, Society, and Enterprise. Each of these chapters in a section highlight work in a selected research group or program aligned to the respective theme. While not exhaustive, this collection should give the reader a very good flavor of what TCS Research is all about. In the Business 4.0 era, when customers are looking at digital and beyond, these essays provide perspectives on what lies ahead in a number of areas. We hope these essays can start conversations about technology and stoke thought leadership.

View

Dr. Gautam Shroff

Dr. Gautam Shroff is the Head of TCS Research. He is a Senior Vice President in TCS and also a TCS Fellow. He has published over 100 research papers in the areas of computational mathematics, parallel computation, distributed systems, software architecture, software engineering, big data, information fusion, virtual reality as well as artificial intelligence including machine learning, deep learning, Bayesian inference and natural language processing. He has written two books "Enterprise Cloud Computing" published by Cambridge University Press, UK, in October 2010, and "The Intelligent Web", published by Oxford University Press, UK, in 2013 (paperback ed. 2015).
Prior to joining TCS in 1998, Dr. Shroff had been on the faculty of the California Institute of Technology, Pasadena, USA (1990 - 91) and thereafter of the Department of Computer Science and Engineering at Indian Institute of Technology, Delhi, India (1991 - 1997). He has also held visiting positions at NASA Ames Research Center in Mountain View, CA, and at Argonne National Labs in Chicago. He completed his B.Tech degree in Electrical Engineering from IIT Kanpur in 1985, and Ph.D in Computer Science from Rensselaer Polytechnic Institute Troy, NY in 1990.