USING ARTIFICIAL INTELLIGENCE TO SOLVE REAL-WORLD PROBLEMS THROUGH TRANSLATIONAL RESEARCH

Prof. Goutam Mukherjee, Director, Institute for Advancing Intelligence (IAI)

Artificial Intelligence (AI) and Large Language Models (LLMs) are becoming increasingly popular. Generative AI tools have become an everyday trend, while techniques such as generative adversarial networks (GANs) and transformer-based LLMs have revolutionised content generation, natural language processing, and data synthesis. These advancements open up new avenues for creating personalised experiences, generating synthetic data for training models, and unlocking insights

from vast amounts of unstructured information. In this regard, there has been a drive towards using sophisticated mathematics in a translational sense to build mathematical models for streamlining how LLMs handle data. Moreover, topological methods have been found very useful for laying the foundations of deep learning and natural language processing.

According to recent market reports, the AI market is expected to grow in value from $11.3 billion in 2023 to $51.8 billion by 2028. Amidst this exponential growth trajectory, the Institute for Advancing Intelligence (IAI), one of the six Centres of Excellence under The Chatterjee Group Centres for Research and Education in Science and Technology (TCG CREST), emerges as a one-of-a-kind research institution that is going beyond traditional academic boundaries to establish itself at the forefront of AI research, translational aspects of Mathematics, and technological advancement.

We speak with Professor Goutam Mukherjee, Director, IAI, TCG CREST, to understand what sets IAI apart and what the nation can expect from this world-class institute in the coming years.

In your perspective, what makes IAI a one-of-its kind institution in India, beyond what is outlined on your website?

Traditionally, in India, most science departments in institutions and universities have had their focus on potential Ph.D. students, and those who did not fit the bill or chose not to pursue Ph.D.s and an academic career had to fend for themselves. Additionally, the faculty in the mathematics or computer science departments at universities had negligible, if any, interactions with science or engineering departments within their institution or with industries. While this trend is slowly changing, with an increasing focus on AI/ML, data science, and analytics, the change remains slow.

To accelerate this transformation, keeping in mind the role India is destined to play in the global scenario in the next few decades, the Chatterjee Group established this Centre for mathematics and computer science in TCG CREST, with the carefully thought-out name "Institute for Advancing Intelligence"—as opposed to "Institute for Advanced Intelligence". The rationale behind such nomenclature is to encourage members of IAI to interact with the other Centres at TCG CREST that are focusing on themes of current interest to society, such as quantum computing, neuroscience, renewable energy, and so on.

We endeavour to provide the best possible environment for learning and research in quantitative, computational, technological, and analytical streams, along with appropriate research tie-ups with leading technology companies and universities of the world. The research courses and other academic activities like seminars, training programmes, and outreach programmes are designed

and planned in an innovative style to meet this goal. Our young and talented faculty members are putting their best efforts into designing academic programmes that can produce skilled resource personnel to meet the demands of sophisticated technology-driven industries and interdisciplinary scientific research.

Carrying out this vision is a ground-breaking, unique endeavour that will set a precedent for the country's vision of an organic, synergistic pursuit of science and technology that can have a tangible impact on society, reaching the lives of every citizen in a positive way.

Students at the Institute for Advancing Intelligence (IAI)

Could you share some memorable moments or achievements that have marked your tenure as Director of IAI thus far?

After taking responsibility as Director, I observed that translational and interdisciplinary research was already being pursued by the talented pool of young faculty members and postdocs of IAI. That being said, it occurred to me that these trajectories of research could be greatly accelerated with increased synergy in a multifaceted way. Thus, my first task was to get the ball rolling on this.

With regard to this I collaborated with our Research & Development Office, headed by Dr. Anirban Chakraborty. The team has been successfully able to enumerate their research in the form of projects, with appropriate personnel being explicitly assigned to each project. This has enhanced the group activity and interdisciplinary research; that I am sure will help IAI reach its goal. I also got the opportunity to initiate a few translational research projects with industries, that have been deeply satisfying.

Currently, IAI focuses on three primary research domains. How do you anticipate these areas expanding in the future? Are there plans to incorporate additional research domains?

The three main research domains at IAI— cryptology and post-quantum cryptology, translational research in mathematics (TRIM), and computer science with a special focus on the applications of AI/ML—are areas of high priority for technology development to advance future growth.

Translational research in cryptology will play a pivotal role in developing security measures in digital India. With the development of the quantum computer, the foundation of classical cryptology has to be revisited thoroughly to take care of challenges to secure digital transactions, computations in scientific research, and quantum information theory with quantum computer. Anticipating this, research in post-quantum cryptology will have to take a position to play a key role in this context.

Mathematical techniques are currently being used in every scientific discipline. Methods of operation research are being used in industry for inventory management, job assignments, and even in quantum computation and quantum chemistry for circuit optimisations. Tools and methods from graph theory are being used in various network analysis problems. Various topological tools are being used in analysing high-dimensional data, which has given rise to the new field of applied algebraic topology and topological data analysis. Existing LLMs are being customised, and computer scientists are collaborating with pure mathematicians to develop efficient LLMs. And needless to say, AI and ML tools are essential in every sphere of new discovery.

We also plan on creating a research group on finance and quantitative economics in the future. However, our current research areas are quite pertinent and active areas as well.

Are there any ongoing projects at IAI that particularly captivate or excite you? If yes, what are some aspects that make them stand out?

We have some current research projects that are very exciting and challenging. One is a project with the Defence Research and Development Organisation (DRDO) on post-quantum cryptology. The aim of this project is to set up a Centre of Excellence in quantum and post-quantum cryptography. In another project, we are working on the development of an AI-ML model to predict responder versus non-responder for lung cancer patients. A third ongoing project is to develop a mathematical model using graph theory for Protein-Protein Interaction (PPI) Network analysis for drug discovery for NDDs. Finally, we are also working on cost optimisation for grade transition in the Haldia petrochemical plant.
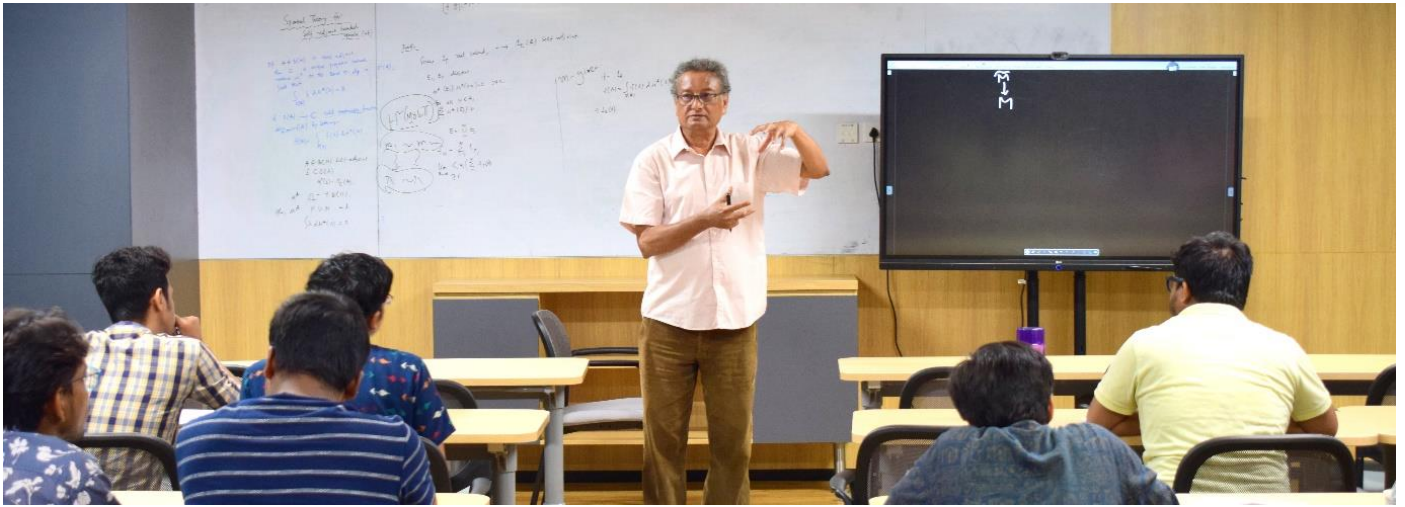
Prof. Mukherjee delivering a lecture at IAI

Given the vision to establish a next-generation world-class institute within India, what unique challenges or opportunities do you perceive in the Indian context?

There is no dearth of talent in India. However, to become a world-class institute, the challenge lies in recruiting talented young scientists who will be interested in aligning their research focus with the institute's vision. We need to proactively reach out to them and provide a conducive, research-friendly environment with infrastructure and other facilities to make TCG CREST their preferred choice. We also need to envision niche, carefully designed syllabi and courses that will provide graduates with the required skills for either industry or academia. India will position itself as a developed country to lead the world in the coming decades, and the institute hopes to support and contribute to the country's growth.

How do you envision IAI contributing to the progress of artificial intelligence and machine learning, considering the increasingly significant role of technology in today's world? Would collaborations with governments or international entities be part of this vision?

We envision playing a pivotal role in advancing AI and ML technologies to address contemporary challenges and leveraging the latest developments to foster innovation, drive research excellence, and facilitate technology adoption across diverse sectors. In fact, one of the key focus areas of IAI

is harnessing the potential of generative AI techniques, such as GANs and LLMs, to fuel creativity, innovation, and problem-solving across various domains.

In line with the IndiaAI mission, we are also committed to fostering collaborations with governments, international entities, academia, industry partners, and non-profit organisations to accelerate the development and deployment of AI solutions that address societal needs, drive economic growth, and promote digital inclusion. Recognising the importance of responsible AI development and ethical considerations in AI applications, IAI is also dedicated to promoting research and initiatives focused on AI ethics, bias mitigation, and responsible AI governance, thereby fostering trust and confidence in AI systems.

Through collaborative endeavour, knowledge sharing, and technology-driven innovation, we can advance the frontiers of AI, empower communities, and contribute to building a sustainable and inclusive future powered by intelligent technologies.

Looking ahead, what potential obstacles do you anticipate in the path forward for IAI?

TCG CREST's vision is challenging, and a dedicated workforce is needed to fulfil it. We need to create a team comprising of both academic and administrative experts. Another major task is necessary revenue generation to build this world-class institute, which will be sustainable. To do this, it is essential to connect with industries, understand their requirements, and provide them with solutions through scientific research that can solve industrial and socio-economic problems. On the academic front, to successfully sustain the institute's academic ambitions, it is imperative to establish connections with other leading institutions worldwide that pertain to the established and planned verticals of TCG CREST. Such a collaborative impetus would allow for a wider reach of the institution while simultaneously ensuring greater exposure for its students to reinforce their research trajectories.

Interview conducted by:

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