tcg crest
Inventing Harmonious Future

FROM ALGORITHMS TO NEURAL NETWORKS:
How Neuroscience Can Inspire Smarter Machines

Why does natural intelligence still outpace our most advanced technologies? Despite our progress in artificial intelligence (AI), including some truly remarkable feats in processing power and data analysis, tasks that are relatively simple for humans and animals—such as recognising objects or navigating spaces—remain surprisingly challenging for computers. This underscores how much we have yet to learn from biological systems, where efficiency and adaptability are fine-tuned by evolution.

Dr. Subhasis Ray, Associate Professor at the Centre for High Impact Neuroscience and Translational Applications (CHINTA)—one of the six Centres of Excellence under The Chatterjee Group Centres for Research and Education in Science and Technology (TCG CREST)—is exploring this intricate interplay between biology and technology. With a background in computer science and a deep curiosity about how the mind works, Dr. Ray's research unpacks the intricate workings of natural intelligence, exploring the intersection between experimental neuroscience and machine algorithms.

Through his groundbreaking work—from exploring how insects process odours to creating tools that accelerate brain research—Dr. Ray is uncovering how nature's blueprints can inspire innovations in robotics, AI, and neuroscience itself.

What motivated your transition from a background in computer science to working on biological neural networks?

As a child, I often wondered how people's minds work. Early in my training in computer science and engineering, I believed it functioned like clockwork, hence there must be an algorithm for the mind. However, while learning algorithm design, I encountered the inverse problem, of translating the human way of solving problems into computer algorithms. This turned out to be possible only for elementary problems. What is simple for computers/mathematics can seem exceedingly difficult for humans. For example, multiplying very large numbers is hard for us, but trivial for a computer. In contrast, stuff that is simple for us, like recognising an object, is extremely difficult for computers/mathematics. This became glaringly obvious as I studied AI as part of my coursework. I felt that we need to study how natural intelligence works before we could genuinely engineer artificial intelligence. Studying computational neuroscience was a natural progression to bridge that gap.

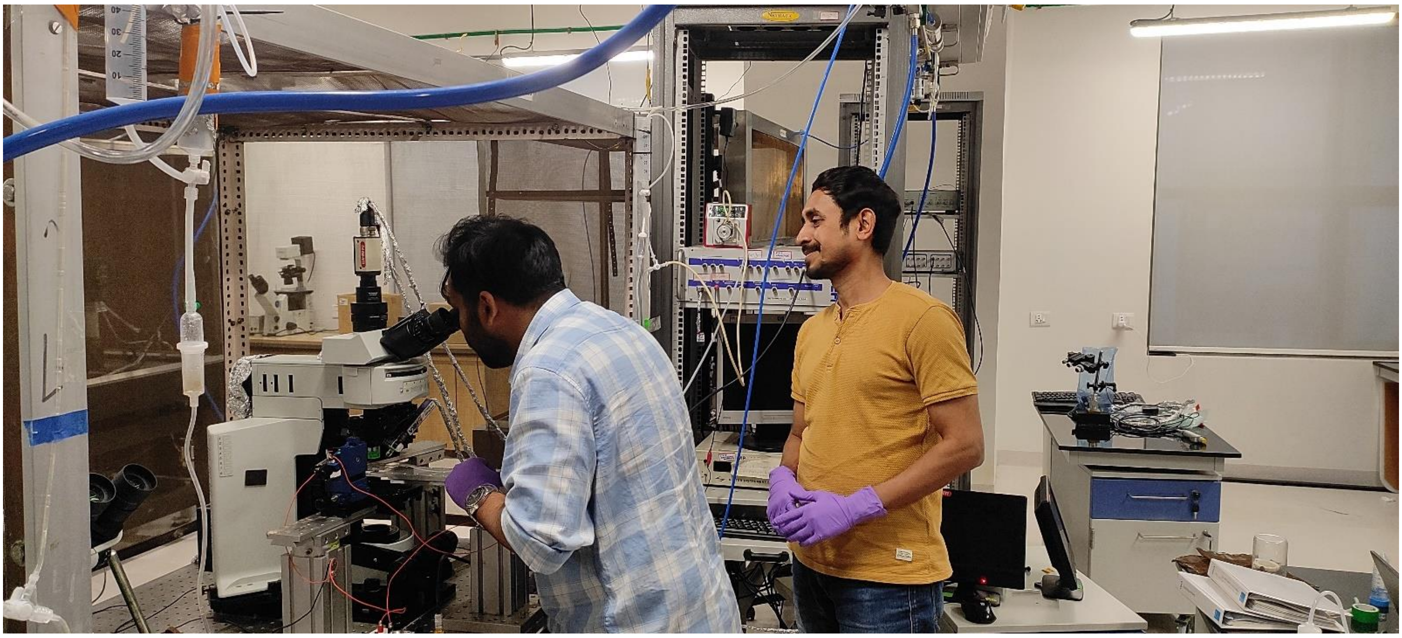
At the National Institutes of Health (NIH), you combined animal experiments with computational modelling. How was experimental research different, and what were some significant findings from your time at the NIH?

Experimental research is a completely different ball game compared to sitting at a computer and tweaking code at your convenience.

First, it took much planning ahead, because each experiment requires a sequence of steps, and most of these steps are timed. There is no pause button for real-world processes. If you mess up one step, the whole thing may go down the drain, and the later it occurs in an experiment, the more effort is wasted. Second, as a corollary, you encounter a lot of failures and disappointments. Many times, I got nothing after performing tedious steps that took a whole week. You may get better at it, but never a hundred percent. In fact, I learnt to invert my view and appreciate each successful experiment as an achievement. I gained a true appreciation for those n's (sample sizes) in experimental research papers, having experienced firsthand the amount of hard work that goes into obtaining those numbers. Third, experiments, especially animal experiments, are very fulfilling, because you are using all your skills. During my undergraduate years we used to feel that many of our courses, like engineering drawing, carpentry, and electronics, were useless. But surprisingly, I found myself using all that training to build my experimental setup! It wasn't just technical skills; there were artistic ones too, as performing a dissection is akin to sculpting. In the end, it was a humbling experience. With pure theory it is easy to lose touch with reality and become an armchair scientist. An occasional slap from Nature helps one separate truth from wishful thinking.

My main work at the NIH was on the neural pathway for processing odour information. I created a detailed computational model of the olfactory pathway in the locust brain. My experiments revealed new properties of a neuron in this pathway, which could not be explained by the existing model. My simulations based on my experimental data suggested a revision of the ideas about the organisation of this pathway.

I also worked a bit on innate attraction and aversion towards specific odours. For this, I developed a software tool using machine learning techniques to track multiple animals in videos. A common idea in the field was that food odour components, which generate strong responses in the brain, are attractive to the animals. Instead, we found that the animals avoided these odorants, starting at concentrations much lower than those used in experiments measuring neural responses. Thus, evoking strong neural response, or being part of an attractive blend, does not imply attractiveness of an odorant.



Dr. Ray with a research staff at the CHINTA laboratory. CHINTA has state-of-the-art laboratories for its faculty and research scholars

What are the applications of your work on modelling neural networks using data science and data mining techniques? Also, what new or emerging technologies do you think will have the biggest impact on advancing your research on neural circuits and sensory processing?

The success of the Human Genome Project inspired large investments in brain research around the world. The European Blue Brain Project graduated to the Human Brain Project, the USA started the Brain Initiative, and Japan started the Brain/Minds project. Additionally, organisations like the Allen Institute and HHMI Janelia Research Campus also invested heavily in brain research. These projects supported collection of high throughput experimental data and making that public, along with related software tools and infrastructure. These projects have now started bearing fruit, making this an exciting time for data-driven neuroscience. Data science and data mining techniques are vital for processing the large amount of data that is being produced in these projects. Moreover, individual researchers can now simply download data from these sources and analyse them to answer important scientific questions. Along with experimental data, standard formats for describing computational models and online databases of published models have also emerged.

I am currently working on a software ecosystem to seamlessly make these accessible to researchers. This will allow someone to browse and download a computational model of a neuron, or a neural network, tweak it, simulate it, and compare the results with experimental data to constrain its parameters. Ten or fifteen years ago this could have taken a five-year Ph.D. to accomplish. Today, we aim to make it possible for an undergraduate student to complete the same task in one evening. You can imagine how much this could accelerate research.

Could your research on neural pathways involved in behaviour have broader applications outside neuroscience, such as in robotics or AI?

Indeed. Existing techniques in AI have seen a lot of successful applications recently, but we still have a lot to learn about intelligent systems from Nature. For example, an insect can navigate its environment, find a mate and sustenance, and escape predators, all with a tiny brain of the order of a hundred thousand neurons. And it does this at minimal energy cost. One could apply the lessons from insect navigation to develop better robots for specific applications. Reinforcement learning, another area of AI, has taken a backseat due to the overwhelming focus on deep neural networks. However, it remains crucial for developing Artificial General Intelligence (AGI), the ultimate dream of the field. Reinforcement learning is based on how animals learn based on reward or punishment. Thus, better understanding these neural pathways in the brain can inform research in this area, which in turn, can drive progress in autonomous robots and AI.

What excites you about being part of TCG CREST? How do you envision contributing to its growth and mission?

For me, the mission of conducting interdisciplinary fundamental research with a global perspective is the most exciting factor. Fundamental or basic research is difficult and takes time, yet in the long run it has the greatest impact. Very few places in India have the far-sighted approach and support systems to nurture such research. We scientists tend to be internationalists by nature, as our work requires sharing knowledge with fellow scientists all around the world, and science itself encompasses the entire universe.

Here, we have a team of internationally trained, world-class researchers, all eager to implement the best practices they have encountered and continuously improve upon these whenever possible. As a first step towards that, we are trying to cultivate a sense of equality and mutual respect, independence, integrity and accountability, critical thinking, and the free spirit of inquiry here. Also, we are trying to create the “global perspective” through international collaborations and exchange programmes, and recruitment of trainees from diverse backgrounds and cultures. Ultimately, we aim to develop world-class research and world-class researchers here.

What role do you think TCG CREST plays in fostering multi-disciplinary research and collaboration in the field of neuroscience and its applications?

At CHINTA and IAI [the Institute for Advancing Intelligence, another Centre of Excellence at TCG CREST], we have been multidisciplinary from the start. Neuroscience, for example, utilises knowledge from digital signal processing, AI, and data science, among other fields. Many of the faculty members have multidisciplinary backgrounds and research areas. By putting together multiple centres with diverse research areas, TCG CREST has created an opportunity for dialogue between these fields, and with time, this is likely to flourish into vibrant collaborations.

What is one message you would like to share with early-stage researchers aspiring to follow in your footsteps?

Do not let society’s expectations set your boundaries.

Interview conducted by:

Research and Development Office, TCG CREST

February, 2025