How Amrita University advanced neurological disorders' prediction using GPUs

Amrita University's Computational Neuroscience Lab adopted the accelerated computing platform to design prediction models for neurological disorders and understand neural circuit function. The aim is to help pioneer treatments for brain disorders and dysfunctions and support developments in engineering and robotics.

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A case study on Predictive Analytics
in Pharma & Healthcare
Mar 17th 2016

The last few decades have seen extraordinary advances in the diagnostic abilities in neuroscience. Key diagnostic tests have become available throughout India and as a result diagnostic accuracy has increased. More and more neurological disorders are being cured, and now several can be also diagnosed locally. As the preventive aspects of neurological diagnosis become expedited in the near future, the full scope of prediction

will become apparent.

Business need

The core of this challenge was the complexity of the vast human brain. Science has only began to scratch the surface of how billions of neurons work together at the molecular level. By looking specifically at the cerebellum, Amrita University, a part of the School of Biotechnology, has started to provide insights into these complex workings.

Only by understanding what causes the brain's functions and dysfunctions can researchers hope to develop treatments for crippling brain conditions. To get to the root of cerebellar disorders, Amrita University initiated a study of the cerebellum's cellular and network components that make up the granular layer of the brain.

> With the GPU accelerators, the university achieved results 30 times faster when compared to conventional CPU-based systems.

To analyze the mechanisms of individual cells, circuits and entire organs, the university created large-scale computational models of neurons and synapses. They used this to perform informational theoretical analysis of how the granular layer responds to sensory and tactile inputs.

Shyam Diwakar, assistant professor and lab director - Computational Neuroscience and Neurophysiology Labs at Amrita University said, "We started by implementing mathematical models on computers to solve relevant medical problems related to the brain and its circuits. Simulating neurological disorders for useful predictions required several long computations. We had very long computation time on a few CPUs, leaving little flexibility and speed. We had to get our calculation times down to seconds and minutes from hours."

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Diwakar said that they were crucially looking at codes being solved by faster computational frameworks. "What we have developed were GPU-accelerated technologies for computationally intensive work in neuroscience. The GPU based solution delivered 15-30x scale-up of speed with certain simulations."

The solution

The university used NEURON, an open-source C++ application for

simulating neuron and circuit models based on ordinary differential equations. The data analysis was performed using GPU-accelerated applications developed in C and MATLAB.

“In our research based at computational neuroscience lab, we used simple models of neurons to build large-scale models of neural circuits. Such circuits were built by taking experimental data from slices of living brain tissue or directly recorded from a human subject or an animal that is alive and then anaesthetized and studied to understand the brain’s responses to certain inputs like touch or grasp,” said Diwakar.

Developing a GPU-based model allowed more complex algorithms and sophisticated network simulations at a much faster computational speed. “We implemented both models of brain circuits in normal condition and how they dysfunction during diseased states. Such modelling allowed predictions of disease and paradigms to treat them.”

> "We are planning to release these set of codes so that anyone may simulate brain circuits and their properties." —Shyam Diwakar, assistant professor and lab director - Computational Neuroscience and Neurophysiology Labs at Amrita University

With the GPU accelerators, the university achieved results 30 times faster when compared to conventional CPU-based systems. This performance boost enabled the team to simulate larger-scale neuron circuit models and develop new data analysis tools.

Benefits and impact

An example application of this research was in understanding the physiological and pharmacological behavior to predict the impact of drugs on brain dysfunctions. “Our primary goal was to seek mechanisms through which some of these conditions can be managed,” said Diwakar.

With GPU based solution, it was easy to reconstruct millions of neurons and understand how they interact with several millions of synaptic connections. It also helped in understanding what happens to these circuits when certain drugs were used to modify or remedy certain behavioral conditions.

Ordinary CPUs could be used for simulations with a small number of detailed models of neurons, but in the case of very large scale simulations, GPUs make it more effective.

“We are planning to release these set of codes so that anyone may

simulate brain circuits and their properties under therapeutic or pharmacological conditions. Besides that, B.Tech, M.Sc. and M.Tech students are also now interested in learning and using these coding strategies to develop their own programming case studies on such technologies," said Diwakar.

"The development of new understandings and perspectives are increasing the prediction and treatment of these debilitating neurological conditions that affect millions around the world," concluded Diwakar.