Comet Helps Replicate Brain Circuitry to Direct a Realistic Prosthetic Arm

By applying a novel computer algorithm to mimic how the brain learns, a team of researchers – with the aid of SDSC’s Comet supercomputer and the Center’s Neuroscience Gateway – has identified and replicated neural circuitry that resembles the way an unimpaired brain controls limb movement. The research, published in the March-May 2017 issue of the *IBM Journal of Research and Development*, lays the groundwork to develop realistic “biomimetic neuroprosthetics” – brain implants that replicate brain circuits and their function – that one day could replace lost or damaged brain cells or tissue from tumors, stroke, or other diseases.

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Let me begin by congratulating Amit Majumdar, director of SDSC’s Data Enabled Scientific Computing division, for being selected SDSC’s “Pi Person of the Year” for 2017. Named after the π symbol, this award recognizes researchers who have one ‘leg’ in a science domain – in Amit’s case neuroscience – and the other in cyberinfrastructure technologies such as data-enabled high-performance computing. Like the symbol, these two areas are both connected and supportive of each other.

Amit participated in a recently published study that used SDSC’s Comet supercomputer and the NeuroScience Gateway project (NSG), which he leads, to help in the development of brain implants that are able to replicate neural circuits and their function. Comet’s stellar capability was used to rapidly simulate and evaluate thousands of possible models to drive a realistic prosthetic arm, while the NSG served as the portal to the computational resources. Read more about that breakthrough in this issue. This is just one of many projects where researchers from all over the world are turning to SDSC’s expertise and systems such as Comet to help them accelerate scientific discovery.

With this newsletter being as much about the people behind the research as the projects themselves, please join me in also recognizing:

SDSC veteran Christopher Irving as our new manager of SDSC’s High-Performance Computing (HPC) systems. Christopher, who joined SDSC in 2011, will also be responsible for learning and testing new technologies for use on our HPC systems. I’d also like to thank Trevor Cooper for serving in that role on an interim basis per his wish after Rick Wagner left late last year to join Globus. Again, more details in this issue.

Ange Mason, our education manager, for her unwavering dedication to raising awareness among middle and high school students in the greater San Diego area about potential opportunities in computationally-based scientific research. We kicked off our eighth (I) annual Research Experience for High School Students (REHS) summer program in June. Kudos to Ange for founding and directing this program, which has helped so many students not only learn more about computational research, but successfully apply to some of the top research universities in the nation including UC San Diego. More details on Page 6 of this issue.

Enjoy this issue of Innovators and have a fun and fulfilling summer!

Michael L. Norman
SDSC Director
Christopher Irving Named SDSC’s Manager of HPC Systems

Please welcome Christopher Irving in his new role as Manager of the SDSC’s High-Performance Computing (HPC) systems. Irving joined SDSC in late 2011 and has been an HPC systems engineer for the past five years. Before joining SDSC he worked at The Scripps Research Institute as a systems administrator in the Automated Molecular Imaging group, a cryo-electron (cryoEM) microscopy laboratory. Prior to that he was with the Massachusetts Institute of Technology as a systems and network administrator in MIT’s Department of Brain and Cognitive Sciences and The Picower Institute for Learning and Memory. Irving holds a B.A. in Computer Science and History from UC Berkeley.

SDSC Applications Programmer Trevor Cooper agreed to serve as SDSC’s Manager of HPC Systems on an interim basis after Rick Wagner left late last year to join Globus as the initiative’s Professional Services Manager in late 2016. Kudos to Trevor for dedicating his time and energies during that period!

Read more at https://goo.gl/6rSJsN

Comet Doubles its GPU Horsepower

SDSC is doubling the number of graphic processing units (GPUs) on Comet in direct response to growing demand for GPU computing among a wide range of research domains. The expansion makes Comet the largest provider of GPU resources available to the NSF’s Extreme Science & Engineering Discovery Environment (XSEDE) project, a national partnership of institutions that provides academic researchers with the most advanced collection of digital resources and services in the world. Once used primarily for video game display graphics, today’s much more powerful GPUs have more accuracy, speed, and accessible memory for more scientific applications ranging from phylogenetics and molecular dynamics to creating some of the most detailed seismic simulations ever made. Under the supplemental NSF award, valued at just over $900,000, SDSC is expanding Comet with the addition of 36 GPU nodes, each with four NVIDIA P100s, for a total of 144 GPUs. This will double the number of GPUs from the current 144 to 288 during the early July timeframe.

Read more at https://goo.gl/6rSJsN

Comet Prosthetics continued from page 1

“The increasing complexity of the virtual arm, which included many realistic biomechanical processes, called for more sophisticated methods and highly parallel computing to tackle thousands of model possibilities,” said Amit Majumdar, director of SDSC’s Data Enabled Scientific Computing division, principal investigator of the NSG, and co-author of the IBM Journal paper. Future studies will focus on developing even more realistic models of the primary motor cortex microcircuits to help understand and decipher the neural code, or how information is encoded and transmitted in the brain.

Read more at https://goo.gl/bPS3kI
Amit Majumdar, Director of SDSC’s Data Enabled Scientific Computing division and an Associate Professor in the Department of Radiation Medicine and Applied Sciences at UC San Diego, was recently named SDSC’s fourth “Pi Person of the Year.” Named after the π symbol, this award recognizes researchers who have one ‘leg’ in a science domain – in this instance the neurosciences – and the other in cyberinfrastructure technologies such as data-enabled high-performance computing. Majumdar participated in a recently published study that used SDSC’s Comet supercomputer and Neuroscience Gateway to create a path to developing realistic “biomimetic neuroprosthetics” – or brain implants that replicate brain circuits and their function – that one day could replace lost or damaged brain cells or tissue from tumors, strokes, or other diseases. Majumdar received his B.S. from Jadavpur University in Calcutta, India, in 1985; his M.S. from Idaho State University in 1988; and his Ph.D. from the University of Michigan in 1996. He joined SDSC in 1997.

Q: Can you describe your involvement in the neuroprosthetics study recently published in the IBM Journal of Research and Development?

Majumdar: We collaborated with researchers at the State University of New York Downstate Medical Center by helping to implement a novel computer algorithm on our Comet supercomputer to mimic a neural circuitry that resembles how an unimpaired brain controls limb movement, in this case to direct a realistic prosthetic arm. Comet provided the capability to quickly simulate and evaluate thousands of possible models, while the Neuroscience Gateway (NSG) based here at SDSC provided an entrance to these resources.

Majumdar is the principal investigator of the NSG project. More details about the study are at https://goo.gl/bPS3kl
**Q: Can you describe how the Neuroscience Gateway is being used by the neuroscience community today and what your expectations are for the future?**

*Majumdar:* NSG helps neuroscientists address computationally demanding problems such as simulation of large-scale network models and extraction of connectivity information from brain imaging data. It has become an important tool for developers of computational neuroscience software from several major universities and research institutions for scientists to disseminate their research to the broader neuroscience community. We already have a user community of over 450, and their yearly usage of supercomputing time is reaching 10 million core-hours across HPC systems at SDSC as well as at the Texas Advanced Computing Center, the Pittsburgh Supercomputing Center, and Indiana University. As a part of NSG we are also getting involved with various neuroscience training programs funded by the National Science Foundation (NSF) and the National Institutes of Health, and we see that the use of an advanced cyberinfrastructure is becoming an important part of neuroscience research and education.

**Q: How is the Data Enabled Scientific Computing group structured and what capabilities does it offer users?**

*Majumdar:* DESC is responsible for the High-Performance Computing Systems group, User Services group, Scientific Computing Applications group, Scientific Visualization group, and the Advanced Technology Lab. SDSC’s involvement in the NSF’s Extreme Science and Engineering Discovery Environment, or XSEDE program, is coordinated from the DESC division. DESC staff members have degrees in domain sciences in areas such as chemistry, computer science, physics, applied mechanics, astrophysics, bioinformatics, and various branches of engineering. All staff members have expertise in high-performance computing, data intensive computing and scientific software. They design and maintain HPC systems and provide user support for our supercomputers, and work on funded research projects involving various scientific applications. More and more analysis of big data problems from various domain sciences and using HPC is becoming of interest.

**Q: Regarding your appointment in UC San Diego’s Department of Radiation Medicine, how can HPC play a role in radiation therapy?**

*Majumdar:* We work with radiation oncologists to see how the computationally intensive parts of various stages of patient treatment plan can be made more efficient using high performance computing, GPUs, etc. Computationally intensive parts include image analysis, dose calculation and optimization of radiation dose delivery. In a clinical setting use of GPUs can be effective and so algorithms and codes need to be implemented and optimized on GPUs. Separately analysis of patient data, which is a data science problem in itself, can also provide insight into effectiveness of treatments and long-term impacts.

**Q: Today, data-enabled science and life science research are dependent upon computationally-based research – in fact they wouldn’t be able to flourish without HPC. Can you share some thoughts on how these areas are intertwined and what you envision in the next 5-10 years or so?**

*Majumdar:* Analysis of data, from whichever field it is, has become a science in itself. Computer scientists, statisticians, mathematicians, and computational scientists are getting involved with domain scientists to understand how data science algorithms such as in machine learning can be applied to solve new and different kinds of problems. In neuroscience, and as a result of advanced experimental techniques, larger and complex data sets are being produced. Data scientists are joining forces with neuroscientists, bringing their data analytics knowledge. All of this will have an impact on HPC – new architectures suitable for machine learning will contribute to new designs for future HPC machines, for example. HPC systems will have to cater to both computational scientists and data scientists by designing comprehensive HPC machines that have the architectural aspects and software stack to serve both the communities including adopting new policies on scheduling, allocation, and even user support.
**The Structure and Statistics of Interstellar Turbulence**

A recently published study in the *New Journal of Physics* by Alexei Kritsuk, a research scientist at UC San Diego’s Center for Astrophysics and Space Sciences, SDSC Director Michael Norman, and Sergey D. Ustyugov at the Keldysh Institute of Applied Mathematics in Moscow examines the properties of turbulence in all phases of the interstellar medium (ISM) by taking into account necessary physics such as radiative cooling and heating of gas as well as magnetic fields. The simulations were carried out in a volume 100 times larger than previous molecular cloud simulations, thereby making them more representative of the ISM. The simulations, which used the computational capabilities of SDSC’s Trestles, Gordon, and Comet supercomputers, extend the results obtained in those earlier isothermal models and place them in a broader Galactic context.

The large background image shows a projected density distribution resembling the structure of the Milky Way’s turbulent interstellar medium in the solar neighborhood. Dense molecular clouds are shown in gold, while more diffuse warm neutral hydrogen is shown in light blue. On the lower left is a reconstructed contour map of the molecular gas, composed primarily of hydrogen. The structure of molecular clouds in this synthetic map mimics that of the Perseus-Taurus-Auriga complex – one of the largest local associations of dark clouds that is 300 to 1,000 light years from our sun – as known from a historic map of this complex compiled some 30 years ago.

Learn more about Dr. Kritsuk’s research at [http://akpc.ucsd.edu](http://akpc.ucsd.edu)
Research Experience for High School Students Gets Underway

June marked the beginning of the eighth-annual Research Experience for High School Students (REHS) summer program, where students are paired with SDSC mentors to gain experience in an ongoing research project or a computation-centric subject. This year, 66 students are participating, which is more than twice the level from just a few years ago. Sixteen SDSC staff are serving as mentors this year.

“We received just over 200 applications for 2017,” said SDSC Education Manager Ange Mason, founder of the REHS program. “We’d love to take them all, of course, but we’re grateful that more SDSC staff are participating as mentors, which has helped expand the program and make it an even bigger success.”

A broad range of student internships are being offered this summer. Subject areas include studying molecular mechanisms of diseases and disorders such as cancer and autism, memory analysis of high-performance computing applications, network and software monitoring and analysis, auto-correlation techniques for seismology research, and multi-scale simulations in chemistry and biophysics.

“Many of our students have kept in touch with their mentors as they start to submit applications to some of the best research universities in the nation including UC San Diego,” said Mason. “It’s very gratifying for all of us to see them pursue a field of computational science.”

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SDSC, NVIDIA Host High Performance GPU Programming/Deep Learning Event

In early June GPU-maker NVIDIA and SDSC hosted a two-day ‘High-Performance GPU Programming and Introduction to Deep Learning’ training session. SDSC received more than 100 registrations for the free event, which was conducted using a hands-on lab format geared for undergraduate/graduate students, post-docs, professors, and researchers including data scientists. Jon Saposhnik, NVIDIA’s Senior Business Development Manager for Higher Education & Research, said it was the best attended training event they’ve had to-date. Kudos to SDSC’s Susan Rathbun and Cindy Wong for coordinating this workshop!
Those of us of a certain age may remember our wonderment in 1999 about hearing our taxi drivers and barbers discussing the killing they were making on the stock of an obscure technology company called JDS-Uniphase. In retrospect, that was a warning sign of the coming carnage. Sometimes it feels the same way with the current discussion around machine learning and artificial intelligence (AI). Not a day goes by without another article in the popular press or a mention on the nightly news of the emerging wonders of AI, whether it is self-driving cars, robots, or reusable space rockets that land themselves upright instead of ditching in the ocean.

Indeed, Gartner Research in 2016 identified machine learning as being at the peak of the hype cycle. However, the current developments in AI and Deep Learning have solid technical foundations that have been years in the making, and seem poised to dramatically impact our daily lives and remake all manner of white- and blue-collar work.

In recent months, SDSC has hosted AI-related meetups and mixers sponsored by the Machine Learning Society and Analytics Ventures, an investment firm focused on AI, machine learning, and the ‘Internet of Things’. Based on the robust attendance and energy level at these events, there is a whole generation of current and would-be technology entrepreneurs in San Diego enthused about building technologies and businesses around AI, and this is exciting.

SDSC scientists are on the forefront of this trend and are conducting research and developing training for AI and machine learning. Our researchers are applying machine learning to autonomous vehicles, cancer treatment, fire fighting, and other fields. SDSC is delivering global online training in big data and machine learning via Coursera and EdX. The recent NSF-funded supplement to augment SDSC’s Comet supercomputer with additional NVIDIA GPUs (graphics processing units) increases that system’s capability for the computational process of “training” deep learning networks. SDSC is eager to engage with industry in high-performance computing, research, and training for AI and machine learning. Please contact us if we can help you achieve your goals in surfing this exciting wave of technology!