The brains behind emerging AI

Computing inspired by the brain's functions has emerged as the next generation of artificial intelligence. THE NATURE CONFERENCE ON NEUROMORPHIC COMPUTING brought together researchers from a wide range of disciplines to discuss the unique challenges and opportunities of this budding field.

Neuromorphic computing uses the physical characteristics and design principles of biological nervous systems to develop artificial neural networks. It seeks to emulate the neural structure of the brain, and its ability to deal with uncertainty, ambiguity, and contradiction. Such a complex endeavour requires collaboration across a wide range of disciplines, including materials science, device physics, electrical engineering, computer science and neuroscience.

Neuromorphic computing is emerging and developing fast. July 2019 saw the announcement of the hybrid Tianjic chip, the first neuromorphic chip enabling scalable configurations of both artificial and spiking neural networks. Developed at Tsinghua University in collaboration with international colleagues, this ground-breaking technology brings together neuroscience and computer science to pave the way for more generalized hardware platforms. "We are fast entering the era of artificial general intelligence (AGI), when chips can rival human-level cross-domain intelligence," said Luping Shi, the Tsinghua professor who led the chip's development.

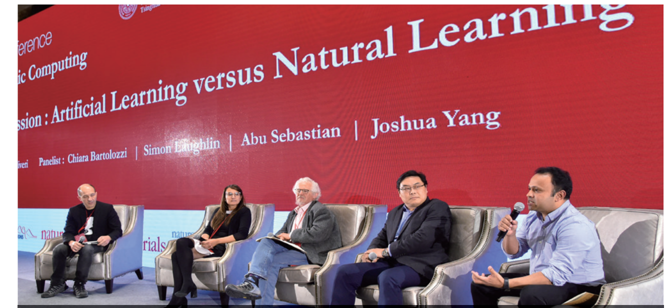
Indeed, according to Stanley Williams of Texas A&M University, 2019 has been a landmark year for this nascent field. He introduced recent advances in neuromorphic computing, including the discovery of a biometric membrane-based memcapacitor, impacting a range of fields such as computing and neurophysiology. "If we are to emulate the brain as a computational engine, we need to understand it as a highly parallel and nonlinear dynamical system," said Williams, who developed the world's first solid state memristor.

Learning from natural intelligence

Simon Laughlin from the University of Cambridge singled out molecular biology as the source of inspiration, saying that the intricacy of protein biochemical circuits can model how protein molecules could compute, transmit and process information. "There is so much to be gained by both reverse and forward engineering of the neuromorphic system, and by sharing the understanding from these two approaches," he said.

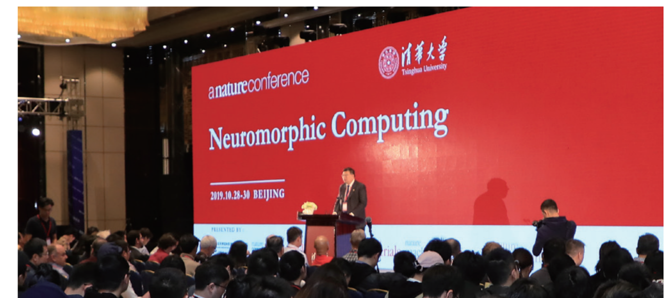
Istituto Italiano di Tecnologia's Michela Chiappalone advocated the "exploitation of neuromorphic computing to communicate with other robotic based systems", noting that prosthetics and other rehabilitation technologies are being developed as implantable devices to deliver personalized solutions. Leading the Event-Driven Perception for Robotics group, her colleague Chiara Bartolozzi outlined how tracking dynamic objects, such as event-based corner detection, will be key for autonomy.

Yulia Sandamirskaya from the University of Zurich and ETH Zurich, Switzerland compared artificial and biological intelligence systems. She discussed navigation, map formation, sequence learning, and adaptive motor control for neuromorphic robots, closing the sensory-motor loop without resorting to non-neuronal computation. "There can be no computing without a proper theory. We need both good theory and good tools," she concluded.

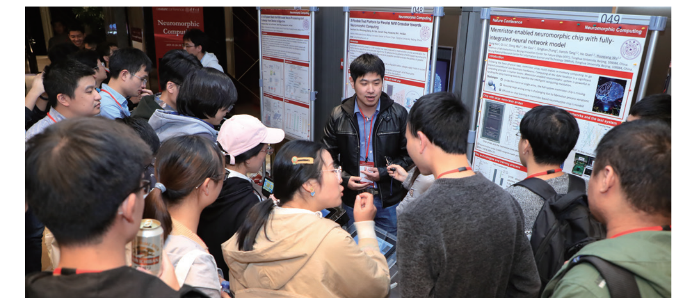


(From left) Moderator Giacomo Indiveri with panellists Chiara Bartolozzi, Simon Laughlin, Joshua Yang and Abu Sebastian


More than 400 industry participants and scientists attended the three-day conference.



The three-day summit welcomed almost 40 top scientists from world-renowned universities, research institutes and international corporations to deliver 38 presentations and three tutorials.


Ten awards were made for the 56 poster presentations, including three awardees from Tsinghua whose simulators and MNIST chips received popular acclaim at the demonstration sessions.

Mastering device architecture and material science

Focussing on intelligent chips, Tsinghua's Shaojun Wei outlined his vision for AI chip 2.0. "If a chip possesses learning capability, its differentiation will strengthen with time," he said. He also introduced the Beijing Innovation Center for Future Chips (ICFC), co-founded by Tsinghua University and the Beijing Municipal Education Commission in 2015. With a team of 200 scientists and engineers, ICFC aims to develop original chips and disruptive intelligent microsystems in the next five years.

Huaqiang Wu from Tsinghua University, deputy director of ICFC, emphasized that emerging AI infrastructure needs far more power and system accuracy than is currently available. However, brain-inspired computing is not equal to high-precision computing, and performance cannot be boosted by simply scaling up CPU and memory. Another challenge is the 'memory wall' where data transfer consumes most of the power, and slow memory limits the performance.

Wu presented a roadmap for perfecting in-memristor computing, evaluated from device, array, architecture, chip, complier and algorithm perspectives. "Powered by a brain-inspired computer with CIM (computation in memristors), we are going to witness revolutionary changes from device level to complier level, in particular cross-layer design for network mapping and analogue computation algorithm technologies," said Wu. "Energy efficiency improvement is also going to jump by two to three orders."

Collaboration for a way forward

During a panel discussion, Herbert Jaeger from the University of Groningen called for "a unifying theory anchor for the long-term survival of the discipline", which sparked lively debate. While appreciating his effort to create an overarching theory, some expressed a greater interest in improving the practical aspects of the field first.

Among them was Walter Senn from Universität Bern. Having previously worked across mathematics and physics, he said that he moved into computational neuroscience to be able to put theory into action. In his own presentation, he proposed a new theoretical framework to derive a biologically plausible implementation of the backpropagation-of-errors algorithm, which is the key to deep learning.

Joshua Yang from the University of Massachusetts Amherst believes that a fundamental shift in curriculum design is required to best equip students to advance neuromorphic computing—a view supported by the other panellists. "Challenge even the 'well-knowns' in this field of unknowns, and even remain critical of published results and theories," he advised in a tutorial session. ■