Background Information

IBM Tokyo Research at CeBIT 2017: Mimicking Neurons with Math

Artificial neural networks have long been studied with the hope of achieving a machine with the human capability to learn. Today's attempts at artificial neural networks are built upon Hebb's rule, which Dr. Donald Hebb, a Canadian psychologist proposed in 1949 as how neurons adjust the strength of their connections. Since Hebb, other "rules" of neural learning have been introduced to refine Hebb's rule, such as spike-timing dependent plasticity (STDP). All of this helps us understand our brains - but makes developing artificial neurons even more challenging.

A biological neural network is too complex to exactly map into an artificial neural network. But IBM mathematician Takayuki Osogami and his team at IBM Research in Tokyo might have figured it out by developing artificial neurons that mathematically mimic STDP to learn words, images, and even music. Takayuki's mathematical neurons form a new artificial neural network, creating a dynamic so called Boltzmann machine (DyBM) that can learn about information from multiple contexts through training.

The team taught seven artificial neurons the word "SCIENCE" (one artificial neuron per bit) in a form of a bitmap image where 1 equate to the lines making up the letters, while 0 translate to the white space around the letters.

What these seven neurons can do all at once is read and write 7-bit information. The word "SCIENCE" is expressed as 7-bit x 35-bit of pattern sequences that equals a 245 bits monochrome bitmap image. These seven neurons read and memorized each piece of the 7-bit information in the image. By memorizing the word from left to right and from right to left, the neurons could recognize "SCIENCE" forward and backward, or in any order – like how we might solve a jumble word puzzle or crossword puzzle.

More neurons. More memories.
Things get more complicated (and interesting) when these artificial neurons learn about different topics in different formats, such as the human evolution image or music. Takayuki's team put 20 artificial neurons to the task of learning this image, which shows how we humans have evolved, from left to right. Why they used 20 artificial neurons this time? One column of the image showing the human evolution consists of 20 bits, and they made it consistent with it.

These neurons learned how the pieces of the image line up in the correct order of evolution – from apes to Homo sapiens. As Takayuki runs simulation, these neurons

Background Information

learn more over time, while detecting the mistakes they make – and making corrections per simulation. With each simulation, the neurons generate an image to show their progress in re-creating the image. It took just 19 seconds for the 20 neurons to learn the image correctly.

Takayuki's DyBM not only memorizes and recalls sequential patterns, but it can also detect anomalies in sequential patterns, and make predictions about future patterns. It could be used to predict driving risks through car-mounted cameras, or generate new music, or even detect and correct grammatical errors in text. Takayuki's work, currently funded by the Japan Science and Technology Agency's Core Research for Evolutionary Science and Technology (CREST), hopes to advance his DyBM by integrating it with reinforcement learning techniques to optimally act on the basis of such anomaly detection and prediction.

At CeBIT 2017, two Researchers from Tokyo will apply their approach to learning in a large number of swarm robots. The neurons provide instant feedback based on pattern recognition, enabling the robots to quickly learn to navigate environments and try to find a target object. In a factory environment, such a learning mechanism, may become useful as an effective alternative for enabling robots to find specific objects. In the future, this may also have the potential to be used for disaster relief support or in archeological explorations.

The scientific paper *Seven neurons memorizing sequences of alphabetical images via spike-timing dependent plasticity* by Takayuki Osogami and Makoto Otsuka appears in Scientific Reports of the Nature Publishing Group on September 16, 2015, DOI: 10.1038/SREP14149.

Media contacts:

June Namioka （波岡ジューン直子）
Communications Manager
IBM Research - Tokyo
e-mail: JUNE@jp.ibm.com

Michael Kiess
Senior Manager
IBM Marketing & Communications
Research & Development