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BRAIN-LIKE SPATIO-TEMPORAL DATA MACHINES

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An enormous amount of data has been accumulated so far and millions of terabytes are being collected every second. At the same time fast computers are now made available performing trillions operations per second. Data is becoming bigger and bigger and computers are becoming faster and faster. Could that lead to a revolution in data analysis and decision support systems, so that many unsolved problems, including better prediction of future events and better decision making, can find their solutions? Yes, but only if there are efficient algorithms and data processing architectures to process properly the big data on the fast computers. This means that we have to develop and explore principally new data processing architecture and algorithms. And that may require a new computational theory.

The Knowledge Engineering and Discovery Research Institute (KEDRI)[1)] is developing and exploring a new type of data processing architectures and algorithms under the name Brain-like Spatio-Temporal Data Machines (STDM). STDM is a computational framework for machine learning and predictive data modelling of temporal or spatio/spectro-temporal data (SSTD).

SSTD is the most common and the most difficult data to deal with. Examples are: brain signals (EEG, MEG, fMRI); medical and bioinformatics data; health data (e.g. personalised records for personalised medicine); audio/visual data; multisensory data (security, sport); ecological data (climate); environmental data (pollution); cyber-security data; seismic data (earthquakes); radio-astronomy data (Pulsars); business and financial data; social media data, etc. SSTD is usually characterised by complex dynamic interactions between spatial/spectral and temporal components. Despite of the enormous amount of such data that has been and is being collected, existing methods have not been efficient in dealing with such data as they can rarely address the complex relationships between spatial and temporal aspects as a dynamic process. So, there is a need for a new paradigm to modelling SSTD in its complexity to enable faster and significantly better pattern recognition, accurate event prediction, much better data understanding and decision support. The STDM offer a radical solution to these problems. The KEDRI STDM is a brain-like computational architecture that utilises artificial spiking neural networks (SNN) as computational units.

SNNs use brain-like information processing principles. Information is represented in the form of *temporal* sequences of binary signals (spikes) that are transferred between *spatially* located neurons. SNNs have the potential for fast, parallel information processing, compact representation of space and time, comprehensive learning and pattern recognition from SSTD. The human brain utilises more than 80bln neurons and trillions of synaptic connections that form complex biological SNNs for the purpose of efficient learning of large amount of information and for early prediction of events that makes the humanity survive. The brain is perhaps the best STDM with its efficient data processing algorithms, optimised by millions of years of evolution. It is not incidental that SNNs have been chosen as the main information processing paradigm for the development of novel neuromorphic hardware systems, the recent ones being able to implement a billion spiking neurons and a trillion of connections, offering high speed and low energy consumption. An example of such system is the Manchester University SpiNNaker neuromorphic platform. However, no theory has been developed yet that underpin the efficient utilisation of SNNs for SSTD, no efficient algorithms to process the big data on these fast machines. And the algorithms are what makes a computer system 'alive'.

The developed by KEDRI STDM is data processing architecture and a conceptual framework for efficient processing of SSTD. It is based on neuromorphic information processing principles and includes SNN modules and algorithms for: encoding-, learning-, classification-, prediction-, parameter optimisation-, visualisation and knowledge discovery from SSTD (see the figure). Spatial/spectral variables of the SSTD are mapped into corresponding spatially located neurons of a scalable 3D SNN structure (of hundred to millions of artificial spiking neurons) so that that the spatial/spectral distance is preserved. The 3D SNN is trained on temporal data in an incremental, adaptive way using unsupervised supervised - and semi-supervised learning methods. The connectivity between neurons in the STDM are evolving continuously to reflect on the spatio-temporal interaction in the data. Our main *hypothesis* is that the proposed STDM will be not only significantly more accurate and faster than traditional statistical and AI methods, but it will lead to a significantly better understanding of SSTD and the processes that generated it.

Main challenges addressed in the KEDRI's research on STDM: integrating large data sets and streams that have different spatial-temporal characteristics (e.g., EEG and fMRI; speech and image); early and accurate prediction of events based on SSTD; optimisation of parameters of a STDM for optimal performance; visualisation of dynamic processes in a STDM to facilitate new knowledge discovery; and finally – the creation of a new, non von Neumann computation theory where the memory of the system resides in its computational space as it is in the brain, rather than in a separate memory device. KEDRI is testing its STDM on data that have different spatial/spectral-temporal characteristics across domain areas, such as: sparse spatial features/low frequency (e.g., ecological data); sparse features/high frequency (e.g. EEG signals); dense features/low frequency (e.g., fMRI and video data); sparse features/high frequency (e.g. seismic data); dense spectral features/fast data streams (e.g. radio-astronomy data; speech and music). Preliminary algorithms for SSTD on SNN have already been successfully tested on the above applications. Solutions to these challenges can have an enormous technological, economic and social impact in the future (Fig. 1).

The KEDRI team, led by Prof. N. Kasabov, works in close collaboration with international partners, such as: Manchester University (Prof. S. Furber and his SpiNNaker team); ETH and University of Zurich (Prof. G. Indiveri); China Academy of Sciences (Prof Z. Hou), Shanghai Jiaotong University (Prof. J.Yang) and many other.[2)]

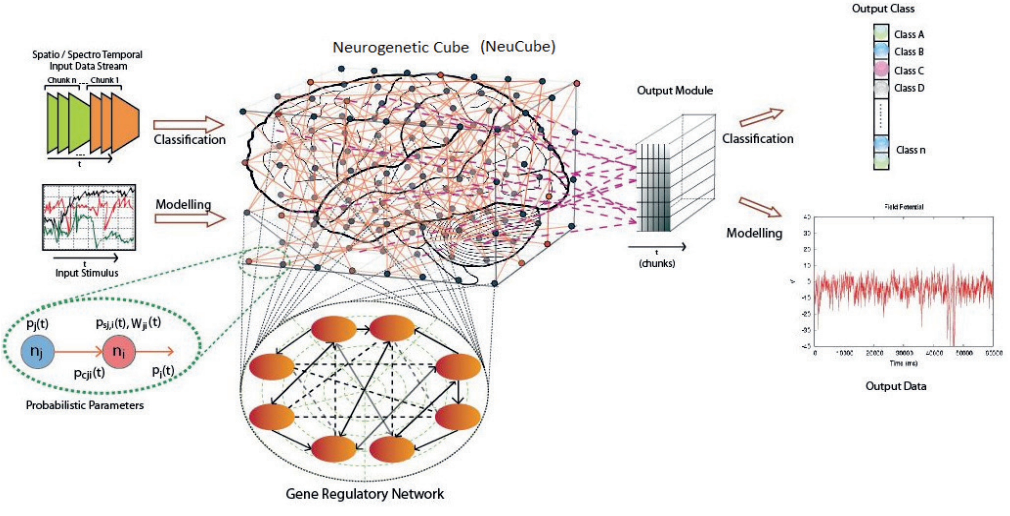

Figure 1. An architecture of a brain-like STDM designed for brain SSTD modelling and analysis (Kasabov, 2014)[3)]

NOTES

1. www.kedri.aut.ac.nz
2. http://youtu.be/Kh51LqtM9Tc
3. More information on the topic can be obtained from the KEDRI web site: http://www.kedri.aut.ac.nz, or from the EU Marie Cuie project site: http://ncs.ethz.ch/projects/evospike. Some results have been also presented by Prof. Kasabov at the IS'2012 (Sofia, Bulgarian Academy of Sciences), ICANN'2013 (TU Sofia) and EANN'2013 (TU Sofia).

REFERENCES

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