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	Talk Title	Order from chaos: engineered systems based on stochastic processes
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1. Tentative Abstract

The human brain is able to perform diverse computations – visual, auditory and other sensory processing; task and strategic planning; abstract thought; coarse and fine motor control – using less than 15-20W of power, and with electronic signals that are so low in potential they are essentially indistinguishable from noise. There is no doubt that the brain's operations must in some sense be stochastic; that is to say, there is an intrinsic degree of randomness in the signals, and all computations are to some extent probabilistic. Modern electronics, on the other hand, are designed to operate in a deterministic fashion, so that noise is eliminated or otherwise overcome, and all computations proceed in a predictable and repeatable fashion. As integrated circuit technologies improve, and device sizes become smaller, the potentials used also become lower and hence noisier; and the likelihood of device mismatch grows (the manufacturing yields, in terms of the percentage of chips which are functional, also fall). There is a consensus that the current electronic paradigm will sooner or later be limited by the noise and randomness that are intrinsic to the physics of nanoscale structures. Neuromorphic systems offer an alternative path in this respect, in that by modeling the brain's function, they benefit from its robustness to noise and structural randomness. A simple example is IBM's TrueNorthneuromorphic chip, which even in prototype manufacturing is achieving yields 5-10 times higher than equivalent FPGA chips of the same size and process complexity (because it is not necessary for every single module of the chip to work perfectly, for it to be functional). We have recently performed a review of electronic methodologies that similarly can cope, or even benefit from, electronic noise and structural randomness.In this presentation we describe a method for building neural networks, both in software and hardware, which intrinsically make use of structural mismatch randomness to achieve their functionality. The randomness is used to create multiple nonlinear projections of input signals. A synthesis or learning algorithm is then used to find a linear combination of these nonlinear projections that satisfies the input-output requirements of the network.

Several applications and implementations of these networks will be described. We have used them for keyword spotting in event (spike)-based auditory representations; for natural language processing of sentences; and for decoding of electrophysiological signals. We have implemented them in a number of technologies, including custom VLSI silicon and on FPGA technologies. Examples will also be given of biological neural structures in which these random projection networks appear to exist, and some theoretical considerations for their presence and application will be addressed.

2. Brief Biography

Jonathan Tapson received his B.S, M.S and PhD degrees from the University of Capetown, South Africa in 1986, 1988 and 1994 respectively. He is currently serving as the Director, The MARCS Institute and Professor in the department of Electrical and Electronic Engineering at University of Western Sydney, Australia. His research area is in electronic sensors and systems, and particularly bio-inspired sensors. He has published over 100 peer-reviewed articles and holds 11 patents. His research has led to the founding of three spin-out companies, and he remains very interested in start-up entrepreneurship. His current research activity focuses on networks which can learn to make decisions in the same way that the human brain performs this task.

3. List of Representative Publications

1. 1. Tapson, J., Cohen, G. and Van Schaik, A., “ELM solutions for event-based systems,” Neurocomputing, vol. 149(Part A), pp. 435-442, Feb 2015.

2. 2. Tapson, J. and Van Schaik, A., “Online and adaptive pseudoinverse solutions for ELM weights,” Neurocomputing, vol. 149(Part A), pp. 233-238, Feb 2015.

3. 3. Hamilton, T., Afshar, S., Van Schaik, A. and Tapson, J., “Stochastic electronics : a neuro-inspired design paradigm for integrated circuits,” Proceedings of the Institute of Electrical and Electronics Engineers, vol. 102, no. 5 , pp 843-859, 2014.

4. 4. Wang, R., Hamilton, T., Tapson, J. and Van Schaik, A., “A mixed-signal implementation of a polychronous spiking neural network with delay adaption,” Frontiers in Neuroscience, vol. 8, no. 51, 2014.

5. 5. Stiefel, K., Tapson, J. and Van Schaik, A., “Temporal order detection and coding in nervous systems,” Neural Computation, vol. 25, no. 2 , pp 510-531, 2013.

6. 6. Tapson, J. and Van Schaik, A., “Learning the pseudoinverse solution to network weights,” Neural Networks, vol. 45, pp. 94-100, 2013.

7. 7. Rapson, M., Tapson, J. and Karpul, D., “Unification and extension of monolithic state space and iterative cochlear models,” Journal of the Acoustical Society of America, vol. 131, no. 5, pp. 3935-3952, 2012.

8. 8. Russell, A., Orchard, G., Tapson, J., Niebur, S., Mihalas, R. and Etienne-Cummings, R., “Optimization methods for spiking neurons and networks,” IEEE Transactions on Neural Networks, vol. 21, no. 12, pp. 1950-1962, 2010.