Workshop on

Energy-Aware COmputing (EACO)[1]

Alternative Models for Energy-Aware COmputation

Wednesday, 19th October 2011, 9:00 - 17:00

Cabot Room, The Hawthorns, 14-16 Woodland Road, Bristol BS8 1UQ

Purpose: To bring together researchers and engineers with interests in *energy-aware computing* for discussions to identify intellectual challenges that can be developed into collaborative research projects. We strive to go significantly beyond the state of the art.

Special focus of this workshop is on **Alternative Models for Energy-Aware COmputation** with one session focused solely on **Learning from Biology**.

Agenda (all times approximate)

Wednesday, 19th October 2011

9:00 **Registration**

9:30 **Welcome and Introduction**
Kerstin Eder and David May, University of Bristol

9:45 **"Prising the secrets of energy efficiency out of brains"**
Simon Laughlin, Department of Zoology, University of Cambridge
~10:45 **Discussion** followed by a short Coffee Break

11:15 **Intellectual Challenges Update and Discussion: What next?**

~12:30 **Lunch** including Networking and Intellectual Challenges Discussion

13:30 **"Energy-Modulated Computing"** - Alex Yakovlev, Newcastle University
~14:30 **Discussion** followed by a short Coffee Break

15:00 **Bring your WILD & CRAZY ideas (WACI) - Brainstorming Session**

~16:00 **Discussion and Conclusion**

16:30 **Wine Reception** and Networking
17:00 **END**

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[1]Supported by the Institute for Advanced Studies (`http://www.bris.ac.uk/ias`) and the Merchant Venturers School of Engineering.

Abstracts

Simon Laughlin, Department of Zoology, University of Cambridge
"Prising the secrets of energy efficiency out of brains"

Abstract: Given that the human brain uses 20% of the body's resting energy it is not surprising that, like most other brains, it has evolved to be energy efficient. Like IBM's Road Runner supercomputer your brain performs in the order of 1015 operations per second, but your brain uses 100,000 times less power and fits in a football. What design principles make brains more efficient? To study efficiency one must be able to measure both performance and cost, and to realise design these must be related to structure and mechanism. For these reasons the detailed analysis of simpler animals and systems - bacteria, nematode worms, flies, guinea pigs and "thoughtless" retinas - has been more revealing than cortex contemplating cortex. I will briefly describe some of the design principles revealed by developing new experimental and theoretical approaches in simpler systems. These principles include save wire, mix analogue and digital, coordinate by wireless, send only what is needed, operate at the lowest rates, process in parallel, exploit chemistry and nanofy. Some of these principles are being implemented in computers, but the brain's enabling technology, its ability to link computing molecules in a cellular architecture and adapt this to ongoing needs, will take some beating.

Prof Simon Laughlin establishes principles of neural circuit design by gathering experimental data from neurons and circuits and developing models that reveal design by connecting mechanism to function. Following a degree in Zoology from the University of Cambridge he obtained his PhD in Neurobiology at the ANU Canberra in 1974, studying photoreceptor optics and retinal processing in insects with Adrian Horridge and Randolf Menzel. He remained in Canberra for a decade, measuring natural image statistics and signal and noise ratios in identified retinal neurons, and working with physicists, applied mathematicians and engineers to pioneer application of information theory to natural stimulus statistics. This new line of enquiry demonstrated how intensity-dependent retinal processing maximizes the uptake of pictorial information. He also worked with William Miller at Yale on the role of protons in rod phototransduction, and with Randolf Menzel in Berlin, on the influence of receptor noise on honeybee colour vision.

Simon joined Cambridge Zoology Department in 1984 and extended his analysis of coding efficiency to the organization and design of basic neuronal mechanisms. He measured the ability of identified synapses to transmit information, characterized the advantages of analogue signal processing in circuits, studied the role of adaptation in motion coding and made the first measurements of the energy costs of the information in sensory receptors, synapses and neurons. He collaborated with David Attwell (UCL) and Gordon Shepherd (Yale), to construct energy budgets for neural processing in neocortex and olfactory bulb, and with Gordon Fain (UCLA) to quantify the metabolic costs of operating rod photoreceptors in mammalian retina.

He is currently using biophysical measurements, stochastic modelling and comparative methods to discover how energy consumption and noise limit the representational capacity of neurons and circuits and necessitate energy efficient circuits and codes. He is also working collaboration Holger Krapp (Imperial College), investigating sensori-motor coordinate transformation and the integration of inputs from multiple sensors in flies, and writing a book with Peter Sterling (University of Pennsylvania) on the principles of neural circuit design. Simon was awarded the Rank Prize Research Professorship in Opto-electronics (1999 - 2004) to work on the biological processing of images, and elected a Fellow of the Royal Society in 2000.

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Alex Yakovlev, Newcastle University, UK

"Energy-Modulated Computing"

Abstract: For years people have been designing electronic and computing systems focusing on improving performance but only "keeping power and energy consumption in mind". This is a way to design energy-aware or power-efficient systems where energy is considered as a resource whose utilization must be optimized in the realm of performance constraints.

Increasingly, energy and power turn from optimization criteria into constraints, sometimes as critical as, for example, reliability and timing. Furthermore, quanta of energy or specific levels of power can shape the system's action. In other words, the system's behaviour, i.e. the way how computation and communication is carried out, can be determined or modulated by the flow of energy into the system. This view becomes dominant when energy is harvested from the environment. This view is also analogous to what happens in biological systems.

In this talk, we attempt to pave the way to a systematic approach to designing computing systems that are energy-modulated. To this end, several design examples are considered where power comes from energy harvesting sources with limited power density and unstable levels of power. Our design examples include voltage sensors based on self-timed logic and speed-independent SRAM operating in the dynamic range of Vdd 0.2-1V. Overall, this work advocates the vision of designing systems in which a certain quality of service is delivered in return for a certain amount of energy.

Alexandre (Alex) Yakovlev was born in 1956 in Russia. He received D.Sc. from Newcastle University in 2006, and M.Sc. and Ph.D. from St. Petersburg Electrical Engineering Institute in 1979 and 1982 respectively, where he worked in the area of asynchronous and concurrent systems since 1980, and in the period between 1982 and 1990 held positions of assistant and associate professor at the Computing Science department. Since 1991 he has been at the Newcastle University, where he worked as a lecturer, reader and professor at the Computing Science department until 2002, and is now heading the Microelectronic Systems Design research group (http://async.org.uk) at the School of Electrical, Electronic and Computer Engineering. His current interests and publications are in the field of modeling and design of asynchronous, concurrent, real-time and dependable systems on a chip. He has published four monographs and more than 250 papers in academic journals and conferences, has managed over 25 research contracts. He has chaired program committees of several international conferences, including the IEEE Int. Symposium on Asynchronous Circuits and Systems (ASYNC), Petri nets (ICATPN), Applications of Concurrency to Systems Design (ACSD), and is currently a chairman of the Steering committee of the Conference on Application of Concurrency to System Design. He is a Senior Member of the IEEE and Member of IET. In April 2008 he was General Chair of the 14th ASYNC Symposium and 2nd Int. Symposium on Networks on Chip, and Tutorial Chair at Design Automation and Test in Europe (DATE) in 2009. He was recently an invited speaker at DDECS 2010, KTN event on Power Management in 2010 and DATE 2011, where he spoke on power-adaptive and energy-modulated computing. He was a visiting professor at Technical University of Vienna in May-June 2011. He was on advisory board of Elastix Corp in 2007-2011. From September 2011 he is a Dream Fellow of EPSRC, UK, to investigate different aspects of energy-modulated computing.