2016 Summer School on Neuromorphic Systems for Machine Learning

Summary of Invited Talks

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Event-Based and Unsupervised Feature Extraction for Neuromorphic Systems

André van Schaik

Research Professor,
The MARCS Institute, Australia

Abstract

Feature detection and extraction is a fundamental cornerstone of computer vision techniques and has been a major focus in conventional computer vision research. The recent upswing in both the popularity and capabilities of event-based cameras has resulted in a similar interest in feature detection in event-based and asynchronous systems. Despite the promising research in this field, there has yet to be a breakthrough feature detection method with the applicability or robustness of highly successful computer vision algorithms like Scale-Invariant Feature Transform (SIFT) or Histograms of Oriented Gradients (HOG).

Part of this problem stems from the unfamiliar nature of event-based data. Whereas the choice of features in a 2D image can be guided by intuition, the same intuition does not necessary carry over to event-based vision. Whereas corners and edges are obvious starting points for features in conventional computer vision, these do not have a straightforward analogue in spatiotemporal domain of event-based sensors.

Unsupervised feature extraction methods, which use statistical and competitive methods to discern features from the incoming data, offer a new way to extract reproducible and scene-dependent features from event-based sources. More importantly, these feature detectors can be implemented in an event-based manner that preserves the temporal resolution of the incoming data. Essentially transforming data into a sparse feature space, the output of these unsupervised algorithms can be used as a basis for classification or are equally well suited for use in hierarchical and deep neural networks.

Biography

André van Schaik received the M.Sc. degree in electrical engineering from the University of Twente, Enschede, The Netherlands, in 1990 and the Ph.D. degree in electrical engineering from the Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland, in 1998.

He is a Professor of Bioelectronics and Neuroscience in the MARCS Institute at the Western Sydney University. His research focuses on three main areas: neuromorphic engineering, bioelectronics, and neuroscience. He has authored more than 150 papers and is an inventor of more than 30 patents. He is a Fellow of the IEEE for his contributions to neuromorphic circuits and systems.

Event-Based Auditory Processing with Spiking Silicon Cochleas and Deep Networks

Shih-Chii Liu

Co-lead of the Sensors group Institute of Neuroinformatics, University of Zurich and ETH Zurich

Abstract

Audio processing based on conventional regular sampling, process audio frames unnecessarily even when the frames carry no information. They also require high sampling rates for auditory scene parsing where source localization and separation are essential. Event-based neuromorphic audio sensors and processing algorithms offer a potential solution to these applications for IoT, mobile, and always-on applications by asynchronously sampling and processing the audio input in a data driven way. This talk covers the latest audio sensing systems including a new sub milliwatt binaural silicon cochlea, event-based algorithms that process the outputs of these cochlea sensors, and example system applications such as auditory localization using a factor of 40 less computing power than conventional Nyquist-rate systems. The talk also covers event-driven deep networks that use the output of the cochleas and the impact of bit precision of such networks on their performance.

Biography

Shih-Chii Liu co-leads the Sensors group at the Institute of Neuroinformatics, University of Zurich and ETH Zurich. She received the B. S. degree in electrical engineering from MIT and the Ph.D. degree in the Computation and Neural Systems program from the California Institute of Technology.

She worked at various companies including Gould American Microsystems, LSI Logic, and Rockwell International Research Labs. Her research interests include low-power neuromorphic auditory sensors and processors; and VLSI event-driven bio-inspired processing circuits, deep networks, and event-driven algorithms.

Dr. Liu is past Chair of the IEEE CAS Sensory Systems and Neural Systems and Applications Technical Committees. She is current Chair of the IEEE Swiss CAS/ED Society and an associate editor of the IEEE Transactions of Biomedical Circuits and Systems and Neural Networks journal.

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Neuromorphic Event-based time oriented vision: A framework to unify computational and biological vision

Ryad B. Benosman

Professor, Neuromorphic Vision and Natural Computation,
Vision Institute, Université Pierre et Marie Curie, Paris

Abstract

The impact of neuromorphic concepts on recent developments in optical sensing and artificial vision is presented. State-of-the-art image sensors suffer from severe limitations imposed by their very principle of operation. These sensors acquire the visual information as a series of ’snapshots’ recorded at discrete point in time, hence time-quantized at a predetermined frame rate, resulting in limited temporal resolution, low dynamic range and a high degree of redundancy in the acquired data. Nature suggests a different approach: Biological vision systems are driven and controlled by events happening within the scene in view, and not — like image sensors — by artificially created timing and control signals that have no relation whatsoever to the source of the visual information. Translating the frameless paradigm of biological vision to artificial imaging systems implies that control over the acquisition of visual information is no longer being imposed externally to an array of pixels but the decision making is transferred to the single pixel that handles its own information individually. It is demonstrated that bio-inspired vision systems have the potential to outperform conventional, frame-based vision acquisition and processing systems in many application fields and to establish new benchmarks in terms of redundancy suppression/data compression, dynamic range, temporal resolution and power efficiency to realize advanced functionality like 3D vision, object tracking, motor control, visual feedback loops, etc. in real-time.

Biography

Ryad Benosman is a full Professor with University Pierre and Marie Curie, Paris, France, leading the Natural Computation and Neuromorphic Vision Laboratory, Vision Institute, Paris. He received the M.Sc. and Ph.D. degrees in applied mathematics and robotics from University Pierre and Marie Curie in 1994 and 1999, respectively. His work covers neuromorphic visual computation and sensing and event based computation. He is currently involved in the French retina prosthetics project and in the development of retina implants and cofounder of Pixium Vision a french prosthetics company. He also actively works on retina stimulation using optogenetics with Gensight Biologics. He is an expert in complex perception systems, which embraces the conception, design, and use of different vision sensors covering omnidirectional 360 degree wide-field of view cameras, variant scale sensors, and non-central sensors. He is among the pioneers of the domain of omni-directional vision and unusual cameras and still active in this domain. He has been involved in several national and European robotics projects, mainly in the design of artifcial visual loops and sensors. His current research interests include the understanding of the computation operated along the visual systems areas and establishing a link between computational and biological vision. Ryad Benosman has authored more than 100 scientific publications and holds several patents in the area of vision, robotics, event-based sensing and prosthetics. In 2013 he was awarded with the national best French scientific paper by the Journal La Recherche for his work on neuromorphic retinas and their applications to retina stimulation and prosthetics.

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Introduction to Neuromorphic Cognitive Computing

Huajin Tang

Professor, Sichuan University, China

Abstract

Neuromorphic computing is a new theme of computing technology that aims for brain-like intelligence, through mimicking the computational substrates and information processing found in the brain. This talk will introduce the major concepts and developments in this emerging area, and discuss the major challenges and problems facing this field. and will focus on some recent research progresses, including spiking based learning, sensory processing, and robotic cognition.

Biography

Huajin Tang received the B.Eng. degree from Zhejiang University, Hangzhou, China, the M.Eng. degree from Shanghai Jiao Tong University, Shanghai, China, and the Ph.D. degree from the National University of Singapore, Singapore, in 1998, 2001, and 2005, respectively. He was a System Engineer with STMicroelectronics, Singapore, from 2004 to 2006. From 2006 to 2008, he was a Postdoctoral Fellow with Queensland Brain Institute, University of Queensland, Australia. He was a Group Leader of Cognitive Computing at the Institute for Infocomm Research, Singapore since 2008. He is now Director of Neuromorphic Computing Research Center, Sichuan University, China. His current research interests include neuromorphic computing, spiking neural networks, and neuro-cognitive robotics. He is an Associate Editor for IEEE Trans. On Neural Networks and Learning Systems, Associate Editor for IEEE Trans. on Cognitive and Developmental Systems, and Editorial Board Member of Frontier in Robotics and AI.

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Spike based visual processing for autonomous vehicles

Garrick Orchard

Temasek Research Fellow, National University of Singapore

Abstract

Garrick Orchard is a Senior Research Scientist at Temasek Laboratories and the Singapore Institute for Neurotechnology (SINAPSE) at the National University of Singapore. He holds a B.Sc. degree (with honours, 2006) in electrical engineering from the University of Cape Town, South Africa and M.S.E. (2009) and Ph.D. (2012) degrees in electrical and computer engineering from Johns Hopkins University, Baltimore, USA. He was named a Paul V. Renoff fellow in 2007, a Virginia and Edward M. Wysocki Sr. fellow in 2011, and a Temasek Research Fellow in 2015. He received the Johns Hopkins University Applied Physics Lab's Hart Prize for Best Research and Development Project, and won the best live demonstration prize at the IEEE Biomedical Circuits and Systems conference 2012. His research focuses on developing neuromorphic vision algorithms and systems for real-time sensing on mobile platforms. His other research interests include mixed-signal very large scale integration (VLSI) design, compressive sensing, spiking neural networks, visual perception, and legged locomotion.

Biography

Bio-inspired event-driven vision sensors, colloquially referred to as "silicon retinae", promise to enable high speed visual sensing and processing at minimal power consumption. These sensors operate on a different principle to frame-based sensors, asynchronously generating output data only when and where specific visual stimuli (in this case changes in intensity over time) are present in the scene. Therefore, unlike a frame-based sensor, the timing and data rate of an event-based sensor output is scene dependent and cannot be predicted beforehand. New tools and methods are required to process this event-based data before the sensors can deliver on their promise of enabling high-speed low-power processing.

This talk will cover our lab's work on algorithms and hardware platforms for processing event-based vision data, with a focus on tackling tasks which are useful for a small aerial vehicle. Such tasks include localization and pose estimation, motion estimation, as well as object and feature detection.

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Smart Image Sensors for Machine Vision

Chen Shoushun

Assistant Professor, Nanyang Technological University

Abstract

Based on commercially available image sensors and powerful personal computers, a series of impressive research work has been reported for machine vision and computational intelligence. Due to the complexity, those signal processing algorithms need to be implemented on very powerful computers. There is a growing gap between the latest computer-based vision algorithms and what is actually implementable in low-complexity hardware. In addition to the complexity of the algorithms, the conventional frame based image sensors employed in these systems also contribute to lower energy efficiency. In fact, the output of conventional image sensors, which is essentially a matrix of pixel color values, contains a very high level of redundancy. Large amounts of unimportant data have to be read and processed before obtaining the features of interest.

This talk will cover the architecture of a number of smart image sensors. Part of the image processing is integrated onto the sensor focal plane, leading to reduced complexity for the post-signal processing. After that, a vision system that combines custom designed sensor and energy-efficient signal processing algorithms will be discussed. It demonstrates the possibility of simultaneously increasing the computational throughput and energy efficiency, for the next generation mobile/embedded vision system, including Satellite, UAV, UGV, and Robotics.

Biography

Dr. Shoushun Chen received his B.S. degree from Peking University, M.E. degree from Chinese Academy of Sciences and Ph.D degree from Hong Kong University of Science and Technology in 2000, 2003 and 2007, respectively. He held a post-doctoral research fellowship in the Department of Electronic & Computer Engineering, Hong Kong University of Science and Technology for one year after graduation. From February 2008 to May 2009 he was a post-doctoral research associate within the Department of Electrical Engineering,Yale University. In July 2009, he joined Nanyang Technological University as an assistant professor.

Dr. Chen is a senior member of IEEE. He serves as a technical committee member of Sensory Systems, IEEE Circuits and Systems Society (CASS); Associate Editor of IEEE Sensors Journal; Program Director (Smart Sensors) of VIRTUS, IC Design Centre of Excellence; Regular reviewer for a number of international conferences and journals such as TVLSI, TCAS-I/II, TBioCAS, TPAMI, Sensors, TCSVT,etc.

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Designing Low-power “Intelligent” Chips in the face of Statistical Variations of Nanoscale Devices: The Neuromorphic Solution

Arindam Basu

Assistant Professor, Nanyang Technological University

Abstract

As CMOS technology has been scaling down over the last decade, the effect of statistical variations (or component mismatch) and their impact on circuit design have become increasingly prominent. Further, new nanoscale devices like memristors and spin-mode devices like domain wall memories have emerged as possible candidates for neuromorphic computing at energy levels lower than CMOS—however, they also suffer from issues of variability and mismatch. In this talk, I will present some of the work done by our group where we take inspiration from neuroscience and show new approaches to perform machine learning with low-energy consumption using low-resolution mismatched components. First, I will talk about “combinatoric learning” using binary or 1-bit synapses—an alternative to weight based learning in neural networks that is inspired by structural plasticity in our brains. Second, I will present an example of utilizing component mismatch to perform part of the computation—an example of algorithm-hardware co-design involving random projection algorithms like Reservoir Computing or Extreme Learning Machine. Lastly, I will show an application of such a low-power machine learner to perform intention decoding in low-power brain-machine interfaces.

Biography

Arindam Basu received the B.Tech and M.Tech degrees in Electronics and Electrical Communication Engineering from the Indian Institute of Technology, Kharagpur in 2005, the M.S. degree in Mathematics and PhD. degree in Electrical Engineering from the Georgia Institute of Technology, Atlanta in 2009 and 2010 respectively. Dr. Basu received the Prime Minister of India Gold Medal in 2005 from I.I.T Kharagpur (awarded to the top student). In the summer of 2008, he worked at Texas Instruments, Dallas and developed automatic tuning strategies for LNAs designed in 45nm and 65nm. He joined Nanyang Technological University as an Assistant professor in June 2010. He is currently an Associate Editor of IEEE Sensors journal (2015-17) and IEEE Transactions on Biomedical Circuits and Systems (2016-18). He is also Guest Editor of two Special Issues in IEEE Trans. on Biomedical Circuits and Systems for selected papers from ISCAS 2015 and BioCAS 2015 conferences.

Dr. Basu received the best student paper award at Ultrasonics symposium, 2006, best live demonstration at ISCAS 2010 and a finalist position in the best student paper contest at ISCAS 2008. He was awarded MIT Technology Review’s inaugural TR35@Singapore award in 2012 for being among the top 12 innovators under the age of 35 in SE Asia, Australia and New Zealand. He is a technical committee member of the IEEE CAS societies of Biomedical Circuits and Systems, Neural Systems and Applications (Secretary Elect) and Sensory Systems. His research interests include bio-inspired neuromorphic circuits, non-linear dynamics in neural systems, low power analog IC design and programmable circuits and devices.

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