MEMRISTOR TECHNOLOGY IN NEUROMORPHIC CIRCUITS

SUMMARY

Conventional computing, including both hardware platforms and computer languages, seems to be close to its physical limits in terms of speed and data density. Classical Von Neumann architectures are known to be great in number crunching, nevertheless, they struggle with tasks like face recognition, real-time navigation control, object segmentation and depth perception. On top of that, CMOS technologies are also approaching the nano-scale floor, with devices attaining comparable dimensions to their constituting atoms, imposing significant challenges on the performance and reliability of analogue and digital circuits hindering the well-exploited correlation of Moore's law with computation capacity.

The imminent barriers to Moore's Law call for disruptive idea of VLSI building blocks for next generation electronics. Responsive efforts span from investigation of new physical state variables other than charge or voltage to novel nanoelectronic devices and circuit architectures offering ultra-dense memory, and low-power logic and reconfigurable hardware architectures. Memristors were first conjectured based on the missing constitutive link between flux and charge by Leon Chua as published in his seminal paper in 1971, which was further extended by L. O. Chua and S. M. Kang in their 1976 paper on memristive devices and systems. Recently physical realization of memristors was reported in Nature by HP's Stan Williams team in 2008.

Memristor potential goes far beyond the attractive possibility of designing a computer where saving at shut down and rebooting at start up are unnecessary or a mobile phone where no battery charging is needed, including one of the greatest technology challenges, i.e. mimicking the functionalities of the human brain. To date, memristor represents the latest technology breakthrough to build electronics devices with characteristics that show an intriguing resemblance to the brain's synapses.

The proposed tutorial aim to address a novel area of research that makes use of a disruptive technology as the fundamental bio-inspired computation element, the memristor.

The tutorial is composed of the following three main parts:

- Neuromorphic circuits and Moore's Law
- Memristor and Memristive devices: from theory to applications
- Memristor synapses for unconventional neuromorphic computing

BRIEF CURRICULUM VITAE

Dr. Fernando Corinto received the Masters' Degree in Electronic Engineering and the Ph.D. degree in Electronics and Communications Engineering from the Politecnico di Torino, in 2001 and 2005 respectively. He also received the European Doctorate from the Politecnico di Torino, in 2005. For the period January 2004-May 2004, he had a temporary full-time appointment as Marie Curie Fellow (within the 'Marie Curie Actions' under the Sixth Framework Programme).
He is currently an Assistant Professor in Circuit Theory with the Department of Electronics and Telecommunications at Politecnico di Torino. His research activity mainly lies in the area of nonlinear nanoscale circuits and locally coupled nonlinear networks.
Dr. Corinto is coauthor of more than 90 international journal and conference papers. He has been reviewer of several papers for international journals and conferences. Since 2010, he is Senior Member of the IEEE. He is also Member of the IEEE CAS Technical Committees on “Cellular Nanoscale Networks and Array Computing” and “Nonlinear Circuits and Systems”. Dr. Corinto is the Technical Program Chair for the 13th International Workshop on Cellular Nanoscale Networks and their Applications and the co-organizer of the 3rd Memristor Symposium. Dr. Corinto is Visiting Professor at Peter Pazmany Catholic University of Budapest, since 2007.

AWARDS

In 2005, Dr. Corinto was awarded a two-year Research Fellowship (supported by CRT Foundation) within the Lagrange Project. The goal of this project was to realize a bio-inspired information processing artificial system, by exploiting cellular nanoscale/nonlinear network based devices, for spatial-temporal computation. Project cost was 60000 €.

RESEARCH ACTIVITY

Fernando Corinto has received IEEE CAS funds (4000 $) for the organisation of a One-day Workshop on Memristor: From Theory to Applications to be held at the Politecnico di Torino (Italy) during November 2011
Fernando Corinto is the principal investigator of the research project (supported by CRT Foundation) ”Nanocircuit arrays for processing spatio- temporal patterns”. Project cost 30000 € for the period 2009-2011
Fernando Corinto is the principal investigator of the research project (partially supported by Istituto Superiore Mario Boella) ”Modelling, simulation and qualitative analysis of genetic regulatory networks via circuit theory and nonlinear systems based techniques”. Project cost 176000 € for the period 2009-2013;

SELECTED JOURNAL PUBBLICATIONS (only related to the tutorial)

[1] F. Corinto, A. Ascoli, “Memristive diode bridge with LCR filter”, Electronics Letters, 5 July 2012, Volume 48, Issue 14, p.824–825 http://dx.doi.org/10.1049/el.2012.1480, 2012

[2] F. Corinto, A. Ascoli, “A boundary condition-based approach to the modeling of memristor nano-structures”, IEEE Trans. on Circ. and Syst.–I, DOI: 10.1109/TCSI.2012.2190563, 2012

[3] F. Corinto, A. Ascoli, and M. Gilli, “Analysis of current-voltage characteristics for memristive elements in pattern recognition systems,” Int. J. Circuit Theory Appl., DOI: 10.1002/cta.1804, 2012

[4] F. Corinto, A. Ascoli, and M. Gilli, "Memristor models for pattern recognition systems", Springer Series in Cognitive and Neural Systems, Vol. 4, Kozma, Robert; Pino, Robinson E.; Pazienza, Giovanni E. (Eds.), ISBN 978-94-007-4490-5, 2012

[5] F. Corinto, A. Ascoli, “Memristor based-elements for chaotic circuits”, IEICE NONLINEAR THEORY AND ITS APPLICATIONS, pp. 336-356, DOI: 10.1587/nolta.3.336, 2012

[6] F. Corinto, M. Gilli, T. Roska, “On Fully Connectivity Properties of Locally Connected Oscillatory Networks”, IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS. I, REGULAR PAPERS, Vol. 58, pp. 1063-1075, ISSN: 1549-8328, DOI: 10.1109/TCSI.2010.2092050, 2011

[7] F. Corinto, A. Ascoli; M. Gilli, “Nonlinear dynamics of memristor oscillators”, IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS. I, REGULAR PAPERS, Vol. 58, pp. 1323-1336, ISSN: 1549- 8328, DOI: 10.1109/TCSI.2010.2097731, 2011

[8] M. Bonnin, F. Corinto, M. Gilli, “Weakly connected oscillatory networks for information processing”, Chapter XXIII of “Bio-Inspired computing and communication networks” Taylor & Francis Group CRC Press, ISBN 9781420080322, 2011