Ph.D. in Information Technology: Thesis Defenses

March 20th, 2019

Room Seminari – 1.30 pm

Alberto BERNARDINI - XXXI Cycle

"Advances in Wave Digital Modeling of Linear and Nonlinear Systems"

Advisor: Prof. **Augusto Sarti**

Abstract:

This doctoral dissertation presents a contribution to the recent evolution of modeling and implementation techniques of linear and nonlinear physical systems in the Wave Digital (WD) domain. The overarching goal of WD methods is to build digital implementations of analog systems, which are able to emulate the behavior of their analog counterpart in an efficient and accurate fashion. Though such methods usually focus on the WD modeling of analog audio circuits; the methodologies addressed in this thesis are general enough as to be applicable to whatever physical system that can be described by an equivalent electric circuit, which includes any system that can be thought of as a port-wise interconnection of lumped physical elements. The possibility of describing systems through electrical equivalents has relevant implications not only in the field of numerical simulation of physical phenomena, but also in the field of digital signal processing, as it allows us to model different kinds of processing structures in a unified fashion and to easily manage the energetic properties of their input-output signals. However, digitally implementing nonlinear circuits in the Kirchhoff domain is not straightforward, because dual variables (currents and voltages) are related by implicit equations which make computability very hard, as instantaneous dependencies between input and output signals cannot be eliminated. Spice-like software, based on the Modified Nodal Analysis (MNA) framework, is not always suitable for realizing efficient and interactive digital applications, mainly because it requires the use of iterative methods for solving multi-variate systems of differential equations. WD Filters (WDFs) are a very attractive alternative. During the seventies, Alfred Fettweis introduced WDFs as a special category of digital filters based on a lumped discretization of reference analog circuits. A WDF is created by port-wise consideration of a reference circuit, i.e., decomposition into one-port and multi-port circuit elements, a linear transformation of Kirchhoff variables to wave signals (incident and reflected waves) with the introduction of a free parameter per port, called reference port resistance, and a discretization of reactive elements via the bilinear transform. Linear circuit elements, such as resistors, real sources, capacitors and inductors, can be described through wave mappings without instantaneous reflections, as they can be all "adapted" exploiting the mentioned free parameter; in such a way that local delay-free loops (implicit relations between port variables) are eliminated. Series and parallel topological connections between the elements are implemented using scattering topological junctions called "adaptors", which impose special adaptation conditions to eliminate global delay-free loops and ensure computability. It follows that WDFs, as opposed to approaches based on the MNA, allow us to model separately the topology and the elements of the reference circuit. Moreover, WDFs are characterized by stability, accuracy, pseudo-passivity, modularity and low computational complexity, making many real-time interactive applications easy to be realized. Most classical

WD structures can be implemented in an explicit fashion, using binary connection trees, whose leaves are linear one-ports, nodes are 3-port adaptors and the root may be a nonlinear element. However, WDFs are also characterized by important limitations. The first main weakness of state-of-the-art WDFs is that fully explicit WD structures can contain only one nonlinear element, as nonlinear elements cannot be adapted. In fact, the presence of multiple nonlinear elements might affect computability, which characterizes classical linear WDFs, as delay-free loops arise. As a second main limitation of traditional WDFs, there were no systematic methods for modeling connection networks which embed non-reciprocal linear multi-ports, such as nullors or controlled sources. Finally, very few studies were presented on the use of discretization methods alternative to the bilinear transform and based on adaptive step-size in WD structures. This thesis presents various techniques to overcome or, at least, to significantly mitigate the aforementioned limitations, showing that the developed WD methods pave the way towards the realization of new general purpose circuit simulation programs characterized by more efficiency and flexibility than mainstream Spice-like software.

Luca Bondi – XXXI Cycle

"Data-Driven and Handcrafted Features for Forensics Analysis and Source Attribution"

Advisor: Prof. **Stefano Tubaro**

Abstract:

The communication power associated with visual content makes digital images a powerful and effective tool to deliver messages, spread ideas, and prove facts. The wide availability and ease of use of image manipulation software makes the process of altering an image simple and fast. This could severely reduce the trustworthiness of digital images for users, legal courts, and police investigators.

This thesis faces several challenges related to the analysis of digital images. The first data-driven method for camera model identification is here presented, showing how modern deep-learning techniques based on Convolutional Neural Networks can be adapted to multimedia forensics tasks. The state-of-the-art algorithm for Photo Response Non-Uniformity compression is here introduced, to solve the problem of large-scale search of picture-device matches based on sensors fingerprints. Anti-forensics techniques and fusion schemes between classical handcrafted features and data-driven approaches are finally presented, to solve some of the open challenges from the multimedia forensics community.

PhD Committee:

Prof. **Matteo Cesana**, DEIB

Prof. **Federico Fontana,** Universita' degli Studi di Udine

Prof. **Giuseppe Valenzise**, Universite' Paris-Sud