Computational Intelligence Techniques in the Analysis and Design of Electronic Circuits and Systems

HABILITATION THESIS

Prof. Gabriel OLTEAN, Ph.D.

Abstract

This work presents my scientific, academic and professional activity since 2002, when the Technical University of Cluj-Napoca conferred me the academic title of Doctor (Ph.D.) in the field of Electronics and Telecommunications Engineering, with Magna Cum Laude distinction.

My research interests primarily consisted in the investigation and exploitation of the possibilities offered by computational intelligence (CI) techniques as fuzzy logic (FL), genetic algorithms (GA), and artificial neural networks (ANN) to address various problems/issues in the field of electronics. My scientific achievements can be organized under some areas of interests, exposed in the "*Scientific achievements*" section.

Automatic design optimization of electronic circuits using CI techniques

This area is related with my doctoral research, where I developed circuit design optimization algorithms, using fuzzy logic. In the post-doctoral research, my contribution was the development of a hybrid intelligent method for the design optimization of analog modules. The method combines some qualities of FL and GA: flexibility to formulate the objective functions and a known range of values, using fuzzy sets; low computational complexity and high accuracy in computing circuit performances by using fuzzy systems; efficiency to search complex solution spaces without being trapped in local minima, using GA.

The proposed method was implemented to act either as single objective optimization or real multiobjective optimization, which generates solutions on the Pareto frontier. The implementation was extended so that a standard circuit simulator was included in the optimization loop to evaluate the circuit performances.

The main results were published in 4 papers, 2 of them included in ISI database.

Functional modeling of analog modules using fuzzy systems

The objective of this research area was to develop a modeling procedure and functional models for some basic analog modules. The proposed modeling procedure is based on fuzzy logic systems (FLS) that are automatically build using supervised training and data sets previously obtained by circuit simulations.

The fuzzy functional models describe the input voltage - output voltage relation in terms of amplitude, frequency and phase-shift and include the temperature effect. All over the frequency and temperature ranges, the models are able to provide the output voltage for a sinusoidal input waveform that keeps the amplifier in its linear region. At low frequency, the models are able to provide the output for a sinusoidal / triangular input, even if the amplifier enters the nonlinear regions.

The results proved the high accuracy and the efficiency of the fuzzy models. These models can be very useful in the design / verification of complex systems at system level where the simulation is performed at behavioral level and tools like Matlab/Simulink are often used.

This research was partially supported by a national research grant, to which I was the grant manager. The main results were published in a book and in 5 papers, 2 of them included in ISI database.

Efficient waveform prediction in electronic systems using CI techniques

My contribution was to develop data-driven methods to build fast and simple to evaluate, but also accurate metamodels, capable of generating not-yet simulated waveforms as a function of different values of the parameters of the system. The novelty is that this represents the first systematic approach of generating signals/waveforms in different points of a complex system using cheap and fast substitutes for extensive simulation.

The method consists of describing the waveform family by a reduced set of features (relevant coefficients of Fourier / wavelet transform), training an ANN to generate this set of features, and finally generating the waveform, using the inverse transform, for any values of input parameters.

Two kind of metamodels were developed: Fourier transform based metamodel, that uses a simple selection of relevant coefficients and optimal wavelet transform based metamodel that uses a GA optimization to detect optimal wavelet transform and to select the most relevant coefficients.

These cost-effective, but reliable metamodels empower the design team to perform extensive analyses of system response, under a theoretically infinite number of different values of input parameters, in a timely manner.

The research was initiated in collaboration with Infineon Technologies, who provides us with a series of industrial early-stage simulation data. The main results were included in a dissertation thesis and published in 4 papers, 2 of them included in ISI database.

Other applications of CI techniques

Other issues that I addressed with computational intelligence technique were: pattern recognition using FLS and ANN, control systems using a FLS as controller, alarming events detection based on audio signal recognition using ANN, and decision making systems based on FLS.

The "*Academic and professional achievements*" section reviews my activities and contributions to the didactic and institutional development components.

Regarding the didactic component, my main achievements were: development and improvement of the subjects I am in charge of, introducing new subjects in the curricula, implication in students' graduation process, publishing 3 books, 7 application manuals, and 3 papers in the education domain (1 in the ISI database).

For the institutional development component the emphasis is on the administrative positions held, representation in national structures, and collaboration with the industry.

The next section "*Management of scientific and academic activities*", refers to my capacity to coordinate research teams and organize and manage teaching and research activities.

For the academic component there were considered: students' appreciation for my teaching activity, supervised diploma projects and master theses and their appreciation by the graduation committees, coordination of students for SSET competition and the received awards.

The scientific component addresses coordination of research activities and research teams in 2 national research grants and my involvement in doctoral programs, especially by co-advising 4 Ph.D. students (we co-authored 11 papers, 6 of them included in the ISI database).

The section "*Career development plan*" brings in my future development plan. My career development relies on all components: didactic, scientific, and institutional. I identified 7 goals to be fulfilled: Orientation towards a student-centred learning; Development of research-informed teaching; Modernization and internationalisation of subjects/study programs; Contribution to knowledge development through fundamental / applied research; Increasing the research visibility; Development of resources; Development of collaborations with industry.

The final section, "*References*", contains the list of the 141 references, out of which I have authored / co-authored 42.