Universitatea Politehnica din București

Habilitation Thesis

ADVANCED HARDWARE AND SOFTWARE APPLICATION OF NEW ELECTRONIC ARCHITECTURES

Domain: electronic engineering, telecommunications and information technologies

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ABSTRACT

The Habilitation Thesis ADVANCED HARDWARE AND SOFTWARE APPLICATION OF NEW ELECTRONIC ARCHITECTURES contains some of the results of my research activity after obtaining the PhD degree in microelectronics, in 1998. In this long period, almost two decades, I was director or member of research team in several research projects. Therefore, the material selected for this thesis covers various topics and is the result of a team effort.

Most of the research projects that are presented in this Habilitation Thesis were conducted by the Center for New Electronic Architectures (CNAE), where I was a researcher since it was founded in 1991. CNAE is subordinated to the DCAE Department of the Faculty of Electronics, Telecommunications and Information Theory of UPB (regarding its scientific activity), and economically is part of the Romanian Academy's Research Institute for Artificial Intelligence (RACAI). For the last ten years, I coordinated the activity of CNAE. Therefore the research activity reported in this thesis is related to the activity of my colleagues from CNAE. I have also worked together with my colleagues from the Faculty, mainly the group of teachers around the course of Digital Circuits. Our cooperation was teaching-oriented but we also had several common research projects.

My PhD Thesis was entitled: "Cellular Automata – a solution for reducing the VLSI complexity" (defended in 1998 at the Politehnica University of Bucharest) contained several applications of cellular automata that I have developed in order to use them in VLSI design. Because of the good results that I have obtained in the thesis, I have continued my research, after PhD, with new applications and new implementations. Most of the results were included in a volume published in 2009 at the Printing House Editura Tehnică: *Cellular automate, modelling and applications* (Automate celulare, modelare si aplicatii), co-authored by Eduard Franti.

Some of the applications that I have explored in the first years after I have obtained my PhD were later developed in long term research projects. For instance, a cellular automata based traffic simulator was the subject of a research project in which, together with the Police of Bucharest and the Town Hall we tried to offer solutions in order to optimize the vehicle traffic in Bucharest. Another successful and interesting research project based on the cellular automata model was the one in which we have designed and implemented a cryptographic system with evolutionary encryption keys. The implementation solution that was chosen – emulation of cellular automata in

FPGA – was the starting point of other designs for some applications that I have developed previously as ASIC. Some of those projects required specific software, as it was more efficient to develop particular software applications with desired functions and graphic interface than to use already available simulators. I took part in the design of the software architecture and I elaborated the models – although other programmers wrote the code – and I ran a large volume of experiments on these applications (that's why I have included some of them in this thesis). The idea was to empirically elaborate libraries with local rules for the cellular automata, in order to elude the problem of cellular automata synthesis. There is no formal or algorithmic solution for CA synthesis, but our pragmatic approach had excellent results for both modelling and processing applications.

A different kind of project explored the artificial societies' paradigm, also related to the cellular automata model. Again, the project started with software development and continued with large scale experiments, but here we were focused to develop theories and explanations of self-organizing phenomena in an artificial environment with simple rules for different types of activities and behaviors.

The most recent projects presented in those thesis are oriented in a completely different direction. Inspired by the post-PhD research of my colleague (and husband) Eduard Franti, who successfully completed a grant that implied the control block of a prosthesis, we have decided to continue this research within CNAE's programs. We had a sequence of projects in which we have realized a locomotor prosthesis, a forearm prosthesis, a sensorial interface for the hand prosthesis that we have called "artificial arm". We have gradually moved from the prosthetic artificial arm towards a robotic arm. We have design a teleoperated robotic arm for cosmic space applications, within a grant of the Romanian Spatial Agency ROSA. However, one cannot say that my research interests switched towards medical electronics and/or robotics, since my involvement was still in the design of the computing architecture, of electronic processing circuits and sensorial interface.

Taking into consideration my research career briefly presented above, the topics selected for this habilitation thesis belong to the last decade long-term projects. The topics were grouped in three chapters, according to the hierarchic type of application: hardware, software and architectures/systems.

The first chapter is the short presentation of my research activity. Chapter 2 presents results in hardware design: an encryption system based on cellular automata. The CA is used to generate

the key, which modifies as the automata evolve. The system was implemented with Xilinx FPGA circuits.

Chapter 3 contains some results in the direction of modelling, simulation and software development. Most of them also start from the cellular automata model, although we have used particular secondary models and variations. The examples selected for these chapter are an encryption software, a traffic simulator and an artificial societies' simulator. In the traffic simulator, we have used traffic modelling with cellular automata, with significant scientific contribution for modelling of several types of conditions and topologies. The model was progressively elaborated from simple to complex and it has very good simulation results, comparing to results measured in street traffic, in Bucharest.

Chapter 4 presents two interdisciplinary projects that implied the participation of the whole CNAE research group, my own contribution is to develop the architectures of the systems and system-level design. The first project is the "artificial hand" – a myoelectric prosthesis with haptic feedback and sensorial interface. The project contains also a telemedicine system with special facilities for training of patients with amputated arms who intend to use a myoelectric prosthesis. The second project, the robotic arm, combines in an original and effective manner elements of data acquisition and virtual reality in order to control remotely an anthropomorphic robotic arm. The purpose of this robotic arm is to operate in environments that are not accessible, or are toxic for the human operator. The most recent results of the project are several feedback loops to improve the accuracy of the commands.

The last chapter – Conclusions – lists the results of the research activity and highlights the recognition of the value of these results: over 50 published articles and over 50 citations prove that the work presented in this thesis contributed to the development of the scientific knowledge. Future direction of research are briefly presented. The domain in which I would like to coordinate PhD students is related to my future research: and microsystems electronic architectures.