PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Innocenzo Mungiello

XXXI Cycle

Training and Research Activities Report – First Year

Tutor: Alessandro Cilardo

1. Information

a. Innocenzo Mungiello, master's degree in Computer Engineering, magna cum laude, in 2015 from the University of Naples Federico II.
b. XXXI Cycle – ITEE
c. No Grant
d. Tutor: Alessandro Cilardo
e. Collaboration with CeRICT in the context of European project MANGO. "MANGO: exploring Manycore Architectures for Next-GeneratiOn HPC systems", is a large-scale European project exploring heterogeneous manycore architectures for HPC, with a particular focus on architectural mechanisms for Performance/Power-efficiency/time-Predictability objectives.

2. Study and Training activities

a. MS Modules:
    i. *Advanced Computer Architecture and GPU Programming*, Alessandro Cilardo, 07/01/2016, 6 CFU;
    ii. *Elaborazione dei Segnali Multimediali*, Luisa Verdoliva, 16/09/2016, 9 CFU;
b. Ad Hoc Modules:
    i. *Communicating and Disseminating your Research Work*, Mo Mansouri, 16/03/2016, 3 CFU;
    ii. *Scientific Writing*, Paolo Russo, 24/05/2016, 5 CFU;
c. Seminars
    i. *Networks-On-Chip: Introduction And Advanced Topics*, Josè Flitch, 16/11/2015 – 18/11/2015, 1.8 CFU (1 extra credit for supplementary activities);
    ii. *Programmable Network conjugation*, Roberto Bifulco, 26/02/2016, 0.4 CFU;
    iii. *Speech Technologies At Trinity College*, Loredana Cerrato, 02/03/2016, 0.2 CFU;
    iv. *Challenging Real-Time Measurement Systems For Immersive Life-Size Augmented Environment*, Giovanni Caturano, 29/04/2016, 0.5 CFU;
    v. *Methodologies for embedded software validation*, Diego Tornese, 25/05/2016, 0.2 CFU;
    vi. *Internet: la dimensione immateriale dell'esistenza*, Stefano Quintarelli, 19/05/2016, 0.4 CFU;
    vii. *DDoS Detection in Cloud and Campus Networks*, Jill Jermin, 06/06/2016, 0.2 CFU;
    viii. *An Overview on Image Forensics with emphasis on physics-based scene verification*, Christian Riess, 18/05/2016, 0.2 CFU;
    ix. *Half Day EMC Design and troubleshooting Course*, Arturo Mediano, 29/09/2016, 0.8 CFU;
    x. *La Protezione Brevettuale, opportunità, procedure, casi di studio*, Giuseppe Mensitieri, 30/02016, 0.5 CFU;

	Credits year 1							
		1	2	3	4	5	6	
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary
Modules	20	0	6	3	5	0	9	**23**
Seminars	5	1,8	0,4	0,7	1	0	1,3	**5,2**
Research	35	7	4	6	4	7	4	**32**
	60	8,8	10,4	9,7	10,0	7,0	14,3	**60,2**

3. Research Activities

a. Title: *Source Code Transformations to Improve Power Efficiency in Many Core Architectures*

b. In the last few years Exascale Computing is constantly gaining importance in the Scientific Community and High-Performance Computers are now considered essential for some experiments in certain areas. For example, in meteorology they are used to create a comprehensive earth system model at 1 Km scale in order to study cloud convection and ocean eddies, or in biology to simulate entire cells at molecular, genetic, chemical and biological levels. Recently, High-Performance Computers have changed in Heterogeneous Systems. In fact, now it is possible integrate in the same system many core CPUs, accelerators like GPU and FPGA. The main reason of this change is the breakdown of the Dennard Scaling due to leakage currents problem, an electrical phenomenon until then ignored. In fact, since 2005, manufacturers have been forced to switch to multi- and many-core architectures. However, also these architectures have reached a limit in terms of peak performance and increasing it, with the current technology, is hard. In this context, the *Performance per Watt* evaluation metric, that is the rate of computation that can be delivered by a system for every watt of power consumed, is gaining more and more importance, even more than peak performance. Several studies have shown that the value of this metric is often lower than desired, because there is a huge overhead essentially due to *data movement* and *memory accesses*. Just consider that for a single floating point operation, we have the 85% of overhead in terms of energy consumption. Therefore, my research is focused on memory management and how its improvements can increase the value of this metric. I want to prove the existence of a strong relationship between the data memory allocation, the conflicts generated by threads trying to access data stored in the banks of shared memories and the power consumption. Actually, I am developing a formal methodology, based on mathematical models like, for example, the Polyhedral Model, and a real implementation of it that can extract information from an algorithm and transform source code in order to achieve a lower power

consumption. Preliminary experiments, done on a NVIDIA Kepler GPU, have proved that changing the memory access pattern can increase the performance per watt by 30% on a set of Rodinia kernels. Another important result I have reached is that some models like the polyhedral or the padding technique, proposed by NVIDIA itself, waste memory in order to solve the conflict problem. This can lead to decreased performance, achieving a counterintuitive effect. With this in mind, my efforts have focused on finding more general models that can also be applied in conditions where the above techniques failed. A first result is the *Adaptive Modular Mapping* technique which has achieved positive results in all operating conditions.

4. Products

a. Publications:

i. Cilardo Alessandro, Mungiello Innocenzo. "Experimental evaluation of memory optimizations on an embedded GPU platform." *2015 10th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC)*. IEEE, 2015.

ii. Cilardo Alessandro, Mungiello Innocenzo, De Rosa Francesco, "Adaptive Modular Mapping to Reduce Shared Memory Bank Conflicts on GPUs" *2016 11th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC)*, 2016.

5. Credit Summary

Student: Innocenzo Mungiello									Tutor: Alessandro Cilardo								Cycle XXXI									
innocenzo.mungiello@unina.it									acilardo@unina.it																	
	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	20	0	6	3	5	0	9	**23**	10	0	0	0	0	0	0	**0**								**0**	23	30-70
Seminars	5	1,8	0,4	0,7	1	0	1,3	**5,2**	5	0	0	0	0	0	0	**0**								**0**	5,2	10-30
Research	35	7	4	6	4	7	4	**32**	45	0	0	0	0	0	0	**0**	60							**0**	32	80-140
	60	8,8	10,4	9,7	10,0	7,0	14,3	**60,2**	60	0	0	0	0	0	0	**0**	60	0	0	0	0	0	0	**0**	60	180