PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Giovanni Cavallo

XXX Cycle

Training and Research Activities Report – First Year

Tutor: Dr. Annalisa Liccardo

1. Information

PhD Candidate: Giovanni Cavallo

MSc title: Master's degree in Electronic Engineering (cum laude), University of Naples Federico II

Doctoral Cycle: XXX - ITEE – University of Naples Federico II

Fellowship type: European Social Fund (ESF)

Tutor: Dr. Annalisa Liccardo

Year: First

I graduated, cum laude, in Electronic Engineering at University of Naples "Federico II". I am a PhD Student of the XXX cycle of ITEE. My fellowship is financed by European Social Fund (ESF). My tutor is Dr. Annalisa Liccardo.

2. Study and Training activities

a. Courses

- Ad hoc Course, "*The Entrepreneurial Analysis of Engineering Research Projects*", Prof. Luca Iandoli, February, *3 CFU*;
- Ad hoc Course, "*Project Management per la Ricerca*", Prof. Guido Capaldo, March, *3 CFU*;
- Ad hoc Course, "*Models, methods and software for Optimization*", Prof. Antonio Sforza, March, *4 CFU*;
- MSc Course, "*Misure su sistemi wireless*", Prof. Leopoldo Angrisani, July, *9 CFU*.

b. Seminars

- "*Teledyne LCroy e Anritsu: Analisi e generazione di segnali ultra-veloci*" organized by Prof. Leopoldo Angrisani, CeSMA, January 23rd 2015, *1.2 CFU;*
- "*Efficeint service distribution in next generation cloud networks*" organized by Prof. Antonia Tulino, University of Naples Federico II, February 10th 2015, *0.8 CFU*;
- "*Three core issues for the Internet: things, security and economics*" organized by Prof. Simon Pietro Romano, University of Naples Federico II, February 19th – 20th 2015, *1.6 CFU*;
- "*The iCub project: an open platform for research in robotics & artificial intelligence*" organized by Prof. Bruno Siciliano, University of Naples Federico II, March 18th 2015, *0.3 CFU*;
- "*Partial possibilistic regression path modeling*" organized by Prof. Antonio M. Rinaldi, University of Naples Federico II, April 20th 2015, *0.2 CFU*;
- "*Microlease e Keysight: Testing Efficace*" organized by Prof. Leopoldo Angrisani, CeSMA, April 24th 2015, *1.6 CFU*;
- "*Rohde & Schwarz: Research and Education Seminar Tour*" organized by Prof. Leopoldo Angrisani, CeSMA, May 18th 2015, *0.8 CFU*;
- "Lagrangean relaxation and Set Covering" organized by Prof. Antonio Sforza, University of Naples Federico II, June 3rd 2015, *1 CFU*;

- "V model design: descrizione ed implementazione di un modello di sviluppo nelle realtà aziendali" organized by Mario Cesarelli, University of Naples, June 6th 2015, *0.4 CFU*;
- "*Italo Gorini 2015*", Doctoral Summer School promoted by the Italian "Electrical and Electronic Measurement" (GMEE) and "Mechanical and Thermal Measurement" (MMT) associations, Catania, September 21st – 25th 2015, 3 *CFU*.

CS Summary

Student: Giovanni Cavallo					Tutor: Dr. Annalisa Liccardo						Cycle XXX				
giovanni.cavallo@unina.it					annalisa.liccardo@unina.it										
	Credits year 1									Credits year 2		Credits year 3			
		1	2	3	4	5	6								
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	Check	Estimated	Check	Total	Check
Modules	20	0	3	7	0	9	0	19	20-40	15	10-20	0	0-10	34	30-70
Seminars	7	0	3.6	2.1	2.2	0	3	10.9	5-10	5	5-10	0	0-10	15.9	10-30
Research	33	10	3.4	0.9	7.8	1	7	30.1	10-35	40	30-45	60	40-60	130.1	80-140
	60	10	10	10	10	10	10	60	60	60	60	60	60	180	180

3. Research activity

My research activity is focused on two most important topics: ***Compressive Sampling*** and ***Terahertz (THz) Technology.***

Compressive Sampling (CS) is an exciting, rapidly growing field that has attracted considerable attention and has already become a key concept in various areas of applied mathematics and computer science. This methodology is used by engineers for a variety of applications in astronomy, biology, medicine, radar and spectroscopy, etc. CS is a sensing/sampling paradigm that goes against the common knowledge in data acquisition. In fact, the conventional approaches to sampling signals or images follow Shannon's theorem: the sampling rate must be at least twice the maximum frequency present in the signal (so-called Nyquist rate). This principle underlies nearly all signal acquisition protocols used in consumer audio and visual electronics, medical imaging devices, radio receivers and so on. The key idea of CS is to recover certain signal and images from far fewer samples or measurements than traditional methods use, using convex optimization algorithms as for example Greedy, TVAL, L1-Magic or CVX. To make this possible, CS relies on two important principles: *sparsity*, which pertains to the signals of interest, which is represented by *k* non zero coefficients, and *incoherence*, which pertains to the sensing modality and in fact incoherence extends the duality between time and frequency and expresses the idea that objects having a sparse representation in a basis must be spread out in the domain in which they are acquired, while sampling/sensing waveform have an extremely dense representation in another basis. The *Compressive Sensing Problem* is the following:

Let $x = x_i \in R^n \; with \; i = 1 \ldots . n$ as our signal of interest. We assume that x is itself *sparse*, it has very few non-zero coefficient in the sense that $\|x\|_0 := \#\{i : x_i \neq 0\}$ is small, or that there exists an orthonormal basis or frame Φ such that $x = \Phi c$ with c being sparse and Φ a matrix with the elements of the orthonormal basis or frame as column vectors. Let *A* be a mxn matrix, which is typically called *sensing matrix* or *measurement matrix*, that is typically a random matrix. Considering that $m < n$ and that *A* doesn't possess any zero columns, the Compressive Sensing Problem can be formulated as follows: recover *x* from knowledge of $y = Ax$, or recover *c* from knowledge of $y = A\Phi c$. In both cases, we have an underdetermined linear system of equations with sparsity as prior information about the vector to be recovered. To solve these underdetermined linear systems we use convex optimization algorithms.

Finally, CS differs from classical sampling in three important aspects. First, sampling theory typically considers infinite-length, continuous-time signals, while CS is a mathematical theory focused on measuring finite-dimensional vectors in R^n. Second, rather than sampling the signal at specific points in time, CS systems typically acquire measurements in the form of inner products between the signal and more general test functions, in which random often plays a key role in the design of these functions. Third, in the Nyquist-Shannon framework, signal recovery is achieved through sinc interpolation, while CS using highly non-linear methods.

THz Technology: Terahertz (THz) frequency region is often defined as the last unexplored area of the electromagnetic spectrum. THz spectrum refers to the frequency domain ranging approximately from 100GHz to 10THz (corresponding to wavelengths from 3mm to 30μm) and having as lower limit the *microwaves*, widely used in mobile and satellite communications, and as upper limit the *far infrared*, where remote control devices and optical communication systems usually operate. Over the past few years, the full access and exploitation of this frequency window in order to close the so-called "THz gap" have been the objective of intense research efforts both in academia and industry. Progress in this area has played an important role in opening up the possibility of using THz electromagnetic radiation (T-waves) in science and in many real-world applications. T-waves are not perceptible by the human eye, are not ionizing and have the ability to cross many non-conducting materials like paper, fabrics, wood, plastic and organic tissues. Such technology can be applied in different areas, spanning from biology to chemical, pharmaceutical, and environmental sciences, and everyday applications within a broad range of industries including the medical, security, cultural heritage, manufacturing and aerospace sectors. The use of THz radiation allows contactless and non-destructive analysis of the materials under investigation both by study of their "fingerprint" via spectroscopic measurements and by high-resolution spatial imaging operations, exploiting the see-through capability of T-waves.

During this first year I spent most of the time improving my background about these two topics and also assisting CS and THz in one only application. In particular, I have tried to realize operations of THz imaging, before using the traditional method of raster scan and then using the method of CS in order to show advantages and disadvantages of these methods. This is possible thanks to the collaboration with Department of Physics of Federico II and in particular with Prof. Antonello Andreone, who has given me the possibility to realize measurements with a THz system, which works in the time domain. About this topic a publication is being prepared, in particular my idea is to show damages or defects reconstructions present in aerospace materials using raster scan and CS.

As next step, my research activity is focused on the definition of a model of measurement uncertainly for THz systems, showing which are all the aspects that can introduce uncertainly and how to limit it. It will be the

high topic, in fact in parallel I will realize via THz spectroscopy measurements on samples (nanotubes of carbon and not only) realized by Department of Chemical, Materials Engineering and Industrial Production, to study their 'fingerprint'.

4. Products

a. Publications

During my first year I have written a chapter for a book of measurement systems and in preparation there is a publication about advantages and disadvantages between raster scan and CS using a THz time domain system (THz-TDS).

- **Chapter Book**
  "THz measurement system" – Prof. Antonello Andreone, Prof. Leopoldo Angrisani, PhD Student Giovanni Cavallo (in preparation);
- **Publication**
  "THz Imaging: advantages and disadvantages of raster scan and compressive sampling" – Prof. Antonello Andreone, Prof. Leopoldo Angrisani, PhD Student Giovanni Cavallo. (in preparation).

5. Conferences and Seminars

I have not participated to conferences or seminars.

6. Activity abroad

I have spent no time abroad during the first year PhD course.

7. Tutorship

Exams Assistant for the B. S. course "Fondamenti di Misure", taught by Prof. Mauro D'Arco, 27 hours.