Ph.D. in Electronics, Computer Science
and Electrical Engineering

Activities report a.a. 2014/2015

Daniele De Vecchi
XXIX Cycle

Tutor: Fabio Dell’Acqua
Scientific activity

Activities during the second year represented a step forward in vulnerability estimation, damage assessment and crowdsourcing. In particular, I took care of the refinement of algorithms for vulnerability estimation already developed during the first year in the framework of the EU-FP7 projects SENSUM and RASOR. Regarding the damage assessment, I started with the evaluation of the correlation between texture measures calculated over VHR SAR images and different layers of damage; speaking of crowdsourcing, a mobile app and complementary algorithms running on a server have been designed in order to collect reports from volunteers.

In details, I had the chance to improve my skills in image processing and risk assessment, combined with knowledge about SAR imagery and their features. These achievements represent a fundamental milestone for the final goal of my PhD thesis, related to the fusion of space-based and crowd-sourced data for vulnerability estimation and damage assessment.

Following, there are overviews of the projects, describing the mission and the ongoing activities.

1. “SENSUM” project

The EU-FP7 project SENSUM, literally “Framework to Integrate Space-based and in-situ sENSing for dynamic vUlnerability and recovery Monitoring”, was designed to deliver innovative methodologies and software tools for multi-resolution monitoring of pre-event vulnerability and post-event recovery assessment. A special focus was on an innovative approach for integration of in-situ observation and space-based products. The project ended in December 2014.

My role in the first part of the second year of PhD was to refine the algorithms already developed during the previous year for vulnerability estimation purposes (work package 2).

The fifth edition of the Pavia International Summer School on Data Fusion for Risk Mapping included a demonstration of the tools developed within the project. Participants had the chance to test and provide feedback on the developed tools.

2. “RASOR” project

The RASOR project (Rapid Analysis and Spatialisation of Risk) is developing a platform to perform multi-hazard risk analysis to support the full cycle of the disaster management. The main goal of the project is integration of algorithms and expertise from the different partners. Pavia role is to provide a set of tools developed within the SENSUM project framework and designed to extract vulnerability indicators. My role during the year was to provide results and documentation regarding the refinement of the developed QGIS plugin.

3. “SEGUICI” project

The SEGUICI project (Smart tEcno logie per la Gestione delle risorse idriche ad Uso Irriguo e Civile, smart technologies for water resources management) has the goal to use crowdsourcing and remote sensing for the management of water resources both for agriculture and civil use. My role, in collaboration with Daniel Aurelio Galeazzo from EUCENTRE was to design and develop a mobile application and a server system. The app will be used by volunteers in order to submit data related to the
status of crops around them. The server side includes automatic algorithm in order to match the contributions with the fields subject of the reports.
The framework of the app and server applications have been designed in order to be very flexible and multi-purpose. The idea is to use the same framework in order to collect other types of data, for example information related to the vulnerability of buildings.

4. Damage assessment from VHR SAR imagery

After an initial literature review related to the topic, I started to process a set of VHR SAR images acquired before and after the L’Aquila earthquake. Experiments are still in progress trying to evaluate the correlation of different layers of damage with texture measures computed over the images.

Educational activities

A lecture of two hours for the “Radar remote sensing” course on the “SENSUM Earth Observation tools”.
A similar lecture of two hours for the “Introduzione al telerilevamento” course.
A theoretical and practical lesson related to the “SENSUM Earth Observation tools” for the GR4S International Summer School held in Pavia in July.

Attendance to seminars, congresses and schools

<table>
<thead>
<tr>
<th>Type</th>
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<tbody>
<tr>
<td>Seminars</td>
<td>“Imparare a progettare in Europa” (February 2015, Pavia, Italy)</td>
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<td>Seminar</td>
<td>“The hidden topology of a noisy point cloud” (February 20th 2015, Pavia, Italy)</td>
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<td>Seminars</td>
<td>“Presentation making” (March 2015, Pavia, Italy)</td>
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<td>Seminars</td>
<td>“Public speaking” (April 2015, Pavia, Italy)</td>
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<td>Seminars</td>
<td>“Fondamenti della comunicazione” (April 2015, Pavia, Italy)</td>
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<td>Seminars</td>
<td>“Scrittura scientifica” (May 2015, Pavia, Italy)</td>
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<td>Congress</td>
<td>Joint Urban Remote Sensing Event (JURSE) (30th March – 1st April 2015, Lausanne, Switzerland)</td>
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<td>Congress</td>
<td>European Geoscience Union (EGU) General Assembly (April 16th 2015, Vienna, Austria)</td>
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<td>School</td>
<td>“Scuola di autoimprenditorialità” (May-June 2015, Pavia, Italy)</td>
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<td>Congress</td>
<td>9th Geo European Projects Workshop (GEPW) (15-17 June 2015, Copenhagen, Denmark)</td>
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<td>Congress</td>
<td>Gruppo Telecomunicazioni e Tecnologie dell’Informazione (GTIT) Riunione annuale (June 17-19, L’Aquila, Italy)</td>
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<td>Congress</td>
<td>Free Open Source Software for Geospatial (FOSS4G) Europe (14-17 July 2015, Como, Italy)</td>
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Congress

International Geoscience and Remote Sensing Symposium (IGARSS) (26-31 July 2015, Milan, Italy)

Congress

Earth Observation Open Science 2.0 (12-14 October 2015, Frascati, Italy)

### Seminars e presentation held

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<th>Title</th>
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<tr>
<td>Presentation A feature based approach to register CBERS CCD and HRC imagery for built-up Area extraction purposes – JURSE 2015 Lausanne</td>
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<tr>
<td>Presentation Automatic hybrid-based built-up area extraction from Landsat 5, 7 and 8 data sets – JURSE 2015 Lausanne</td>
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<tr>
<td>Presentation An integrated, open-source set of tools for urban vulnerability monitoring from Earth Observation data – EGU 2015</td>
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<tr>
<td>Presentation Monitoring of urban vulnerability from Earth Observation data: a novel, open-source set of tools – GEPW 2015</td>
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<tr>
<td>Presentation Vulnerability estimation and damage assessment as combination of remote sensing and crowdsourcing – GTTI 2015</td>
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<tr>
<td>Presentation A small step towards the citizen sensor: a multi-purpose framework for mobile apps – IGARSS 2015 Milan</td>
</tr>
<tr>
<td>Presentation Unsupervised change detection for urban expansion monitoring: an object-based approach – IGARSS 2015 Milan</td>
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### Stay abroad

None.

### List of publications

#### 1st year


3. M. Harb, D. De Vecchi, F. Dell’Acqua. “A novel approach in co-registering remotely sensed


2nd year


Ph.D. in Electronics, Computer Science and Electrical Engineering

Activities report a.a. 2014/2015

Paolo Farinello

XXIX Cycle

Tutor: Prof. Antoniangelo Agnesi
Scientific activity

1. High spectral resolution LIDAR for spaceborne applications.

Standard LIDAR (Light Detection And Ranging) systems provide profiles of the attenuated backscatter (input laser) signal from the atmosphere. Difficulties in extracting information about atmospheric properties however arise as this signal comprises different entities coupled to each other. High Spectral Resolution LIDAR (HSRL) exploits the difference in the Doppler frequency shifts produced when photons are scattered from molecules in random thermal motion (~1 GHz) and aerosols driven by the wind (~30 MHz), to produce independent signals according to the particle size. In order to meet the requirements of the HSRL technique, the system employs a narrow bandwidth laser source as transmitter.

During my second year of PhD I worked on the oscillator which is intended to drive the entire laser source of the LIDAR system. In order to satisfy the requirements of the project we adopted a technology based on a monolithic microchip device, consisting in a thin piece of Nd:YVO$_4$ gain medium with both facets coated to serve as mirrors of the optical cavity. This solution represents an innovative alternative with respect to the possibility to seed an oscillator with a CW laser diode in order to select narrow single longitudinal mode, offering the following advantages: the system we propose is capable to provide peak power levels far in excess than the ones exhibited by CW injection seeded counterparts, besides granting an intrinsically much more stable spectrum, ending up in reduced laser system complexity (no need to actively lock the cavity length to the frequency of the seeder) and better amplification performance.

The microchip oscillator is driven to operate in gain-switching regime: the laser is prevented to fully relax to its CW behavior suitably reducing the pump pulses duration, until a single relaxation oscillation is triggered. In comparison with the Q-switching technique, involving the introduction of additional optical elements modulating the losses inside the cavity, gain-switching is simply achieved appropriately tailoring the shape of the pump pulses, improving the system robustness and fostering low cost and mass production of microchips.

Typical system performance in single relaxation oscillation regime exhibits conversion slope efficiencies as high as 60%, diffraction limited TEM$_{00}$ spatial behavior and single longitudinal mode. A spectral bandwidth of ~67 MHz was measured by means of a scanning Fabry-Perot interferometer. Pulse duration
and output power registered with 10 kHz repetition rate and 500 ns long pump pulses are respectively ~8 ns (confirming that the laser pulse is almost Fourier limited) and < 1 mW.

Preliminary amplification demonstration up to 3 W power levels was accomplished by means of a CW diode pumped solid state amplifier, with the output beam still maintaining diffraction limit spatial quality ($M^2 \sim 1.3$). The ASE contribution to the amplification process was found to be negligible, as it is suggested by second harmonic conversion tests, revealing efficiencies as high as 57%.


In the framework of the tests on new non-linear crystals for Stimulated Raman Scattering (SRS), an improvement of the experiments performed on SrWO$_4$ during the first year of PhD was possible thanks to the availability of new samples, with different lengths and both facets properly coated at the operation wavelengths.

The new samples were tested again with different pump laser sources, providing pulses with diverse durations, in order to investigate all SRS regimes. Conversion efficiencies close to the quantum limit set by the ratio of the pump and Stokes wavelengths (~90%) could be observed, with a beam propagation factor of the Raman beam only slightly degraded ($M^2 \sim 2$) with respect to that of the pump. The measured peak powers of the Raman shifted pulses (> 300 kW) are ideal for application in nonlinear processes, including second harmonic generation and pumping of mid-infrared parametrical devices.
**Education activities**

1. Industrial Laser Design.

**Attendance to seminars, congresses and schools**

1. *Imparare a progettare in Europa*, course, speaker Dott.ssa Sofia Baglini, Università degli Studi di Pavia (Italy), 10 – 11 and 18 February 2015.

2. *Python programming for machine learning*, course, speaker Blaz Zupan and Marinka Zitnik, Università degli Studi di Pavia (Italy), 18 – 20 February 2015.

3. *Course on “Cloud Computing”*, course, speaker Dana Pectu, Università degli Studi di Pavia (Italy), 28 – 29 April 2015.

4. *A 2-16 GHz stepped frequency integrated radar for breast cancer diagnostic imaging in 65 nm CMOS*, seminar, speaker Andrea Bevilacqua, Università degli Studi di Pavia (Italy), 14 January 2015.

5. *The hidden topology of noisy point cloud (Part I and II)*, seminar, speaker Andrea Pedrini, Università degli Studi di Pavia (Italy), 20 March 2015.

6. *The hidden topology of noisy point cloud (Part III)*, seminar, speaker Andrea Pedrini, Università degli Studi di Pavia (Italy), 27 March 2015.

7. *Metrology with/for MEMS/NEMS devices*, seminar, speaker Teodor Gotszalk, Università degli Studi di Pavia (Italy), 20 April 2015.

8. *Optofluidic lab-on-chips for cell manipulation fabricated by femtosecond lasers*, seminar, speaker Francesca Bragheri, Università degli Studi di Pavia (Italy), 27 May 2015.

9. *Metodi e strumentazione per analisi mixed domain a misure ad alta sensibilità*, seminar, speaker Giakova, Università degli Studi di Pavia (Italy), 28 May 2015.

**Seminars and presentations held**

Stay abroad

List of publications

First Year:


Second Year:


Ph.D. in Electronics, Computer Science and Electrical Engineering

Activities report a.a. 2014/2015

Takai Eddine Kennouche
XXIX Cycle

Tutor: Lorenzo Favalli
**Scientific activity**

The Focus of the second year of the PhD program was mainly on Developing a General Simulation Framework for Cognitive Radio and Heterogeneous Networks based on the NS-3 Simulator. This involved the study of 802.22-2011 Standard and adopting the System Architecture defined within for our Simulator. This work allowed me to have a deeper understanding of different aspects of Cognitive Radio Technology, the different challenges and solutions and the state of the art of current implementations and techniques and their future developments.

The work on the General CR Simulation Framework opened multiple opportunities for collaboration, not only from Network Simulation perspective but also interfacing with real hardware and network emulation, especially during the period I'm passing at the Wireless Lab at Northeastern University. All that should be culminated by a number of Journal/Conference publications to share the different results and achievements with the scientific community.

**Education activities**

<table>
<thead>
<tr>
<th>Course</th>
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<tr>
<td>Linguaggi, problemi metodi della comunicazione in ricerca scientifica, Collegio Nuovo, Pavia</td>
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**Stay abroad**

- 08/2015 – 02/2016: Northeastern University. Boston, USA

**List of publications**

**Conference proceedings**

FORENSIC DATA MINING

Ph.D. in Electronics, Computer Science
And Electrical Engineering

Activities report A.A. 2014/2015

Dario Lanterna
XXIX Cycle

Tutor: Antonio Barili
Fragment Data Mining

Background

Last year - the first in my course of study - I surveyed the basic element of digital forensics, including elements of civil and criminal law that are needed for a good understanding any forensic procedure. This made me aware of the state of the art of digital forensics.

I then started working on metrics applied to file fragments characterization. I developed a set of metrics and I applied them to clustering problems.

I found that this approach, frequently cited in literature, is too simplistic to be useful in practical fragment classification. That yielded me to the study of fragment lexical and syntactical structure that I conducted this year.

Activities

A text fragment is any sequence of characters: in the digital forensic domain fragments usually come from some process of file carving applied on a digital storage media. Previous works focused on clustering file fragment sets. We must now analyze the content of each cluster and try to detect file type or file structure type through lexical and semantic analysis of each fragment. The knowledge of the file structure allows us, for example, to separate html tags from meaningful content. Using semantic analysis we can also detect fragments coming from the same file.

File formats are set of rules defining the syntax of the file file, encoding rules and content organization. Some files are structured as object containers. In this case, each inner object has its own format.

Detecting the file format of whole files is quite simple. Filename extension, internal metadata, file header and magic numbers may all be used to identify the format. However, if we have a fragment some elements may be missing.

Using a lexer (lexical analyzer), whose output is a set of tokens, we can extract new information items. Tokens may be, for example: email addresses, email boundary markers, url, keywords, numeric real/integer, word (sequence of alphabetical letters) and symbols. Token sets may be used to compute similarity and to accurately cluster files fragments.

A syntactical analyzer may be used to detect more complex structures. Its output is a partial parse tree that can be matched to parse trees typical for a given file format.

Detecting and correctly classifying file fragments is of the highest importance in the forensic analysis of digital media, since most artifacts like hibernation/swap files, a memory dumps, a network traffic dumps, and the content of a disk in a deduplicated system only provide partial information instead of complete files.

File fragments can be also originated by carving an highly fragmented file system. In this case the allocation process of a large file necessarily creates many file fragmentation. Carving process give all the fragments of the original file. Using the grammar is possible to detect the elements of the file and rebuild the whole file. The correct sequence of the fragment give no error during syntax analysis.

However, we can also tag each fragment with incomplete grammar rule present at the beginning and at the end, to simplify the fragments hunting. Similar procedure can be applied deduplicated storage
device. Recent storage system products permit data deduplication. Deduplication operates on blocks fixed or variable length; it stores once each different block. Deduplication generate a fragmentation as a result, and carving on a deduplicated disk generates a big number of fragments.

Another type of fragments is generated by allocating new files in a disk block that are smaller than the previous file. In this case is not possible recover the whole file, but is important to extract any useful element.

Lexers and parsers used in the analysis process are often heirs of the popular lex & yacc. The version used is PLY (Python Lex and Yacc). PLY is a LR-parser structured to use large grammar and to parse very large file. The PLY error-checking engine is very flexible and allows customizing action as needed in the analysis.

Next year work

Modern digital forensics covers different areas of interest: live systems, virtual and cloud system, deduplicated system, and their mix. The procedures studied in first two years will be applied to data coming from these areas. Their limits of application will be studied, as their accuracy will be estimated.

Forensic investigations in large organisations require an approach called live forensics. In those environments data are stored and processed in server infrastructures. Switching off the system and seizing all computing device is difficult (if it is ever possible) and can create an unjustified economic damage. On the other side data can be seized from live system, memory dumps and capturing live network traffic. If investigation allows a more intrusive approach it is possible to run tools that convert physical computer to virtual machine (P2V) and to seize the converted virtual machine.

Virtual environments infrastructure are used to supply cloud services. Virtual server can be seized as a snapshot image of the working virtual machine. This image contains the full disk and, if required, a memory dump. Carving those artifacts generate the same content of an offline disk or a memory dump analysis.

Moreover, the computing infrastructure make large use of backups and archival procedures, and those data are stored in deduplicated virtual tape library systems. If the system administrator extracts the data properly during investigation you get the whole files, but if data must be recovered from a lower level analysis, this type of storage contains only fragments.

Incident Response Analysis

Background

From March to the end of April 2015 an anomalous traffic, targeted the IP address of one of the web
servers of the University of Pavia. The overall effect was similar to a DDoS Attack. To analyze the event we assigned a new IP address to the web server. A honeypot take charge of the original IP address, and we investigate the causes of the event.

Activities

The honeypot ran in a virtual machine was a standard Linux-Apache (LAMP) web server. It collected traffic data on ports 80 (HTTP) and 443 (HTTPS). Iptables filters dropped all the network traffic directed to other ports. To avoid overflow in kernel memory we tuned kernel parameters, the configuration allow to handle the huge amount of incoming connections.

Traffic volume was stable during the period under investigation, averaging to 1.77 Mb/s, far lower than the capacity of the network link of the Data Center (1 Gb/s). The overall data received averaged to 22 GB/day.

The honeypot logged more than one million HTTP and HTTPS requests per day, from about 300,000 different IP addresses. About 97% of all requests came from IP addresses located in China, followed by US and Japan. Each day there were requests for 12,000+ different http-hosts belonging to 2,000+ different domains. All HTTP and HTTPS requests were well-formed, but the http-host field did not pointed at our FQDN (i.e. traffic were originally directed to another host). The hypothesis was a bad response from some DNS around the world. Querying Chinese OpenDNS servers for each of misdirected http-hosts, we received many different IP answers, even within the same minute.

Clustering client IP for geolocation it was evident that there was only a 3% of requests coming out of China. Investigating around this 3% requests, a detailed traffic logs analysis, revealed that the Google Spider had visited our honeypot while trying to index a site named oyffy.aghg0088comdaili.com and many others. Since the Google Spider is supposed to use Google’s DNS servers (8.8.8.8 and 8.8.4.4) we revealed that those DNS servers had been indirectly poisoned.

Chinese policies to filter some sites when accessed from China is well known, the indirect poisoning of Google DNSs shows that such policies spread their effects even outside China borders. Additionally we found that if anyone, anywhere, tries to visit sites registered in China but apparently falling under their filtering policies (e.g. tevf.aghg0088comdaili.com), Chinese DNS servers will return a poisoned response. This response is cached outside China, thus adding to the poisoning spread.

Chinese Internet filtering policies have been in place for a long time, the large scale DNS poisoning recently deployed can spread its effects far over GFW and China borders. Unknowing sites may suddenly become target of the DDoS-like traffic generated by the poisoning. It is not clear how these targets are selected; the large majority of the targets we discovered is apparently selected random. Even if the traffic per site is not that large, some sites – especially those running application servers may experience severe application DoS effects. The volume of traffic per target, is large enough that it may easily exhaust the monthly volume available to smaller sites, thus creating an economic DoS (EDoS) effect.
Users on the internet, trust elements of the networks, that haven’t a declared their level of
dependability. The most important of this element is the configured in their devices DNS. The DNS
poisoning is the simplest method used to filter sites, and is implemented by almost all ISP, as well as
companies, schools, and governments themselves.

Poster international conference

*On the Effects of Large-Scale DNS Poisoning*, Antonio Barili, Dario Lanterna, IEEE CNS 2015

Age Estimation project

Background

During the first year, in collaboration with the Department of Brain and Behavioral Sciences, we
analyzed age estimation using human subjects. Subjects were also administered psychological test. This
year we analyzed a similar problem in collaboration with Laboratory of Multimedia Databases (Dept. of
Eng. – Prof. M.G. Albanesi, Dott. R. Amadeo) and we tried to correlate result with metrics studied for
Quality Assessment.

Activities

Starting from the same set of face images used last year, we applied a set of transformations to obtain
two different type of de-aging effects. The first transformation was a semantic structures
transformation, made automatically. The second was a series of geometric manual transformation.

We used full reference metrics, PSNR (Peak Signal-to-Noise Ratio), VIF (Visual Information Fidelity), SSIM
(Structural SIMilarity index), GSSIM (Generalized Structural SIMilarity index), CW-SSIM
(Complex-Wavelet Structural Similarity Index).

The hypothesis was: since there are metrics to evaluate “quality” of an image, and these metrics
perform well, is possible to use similar metrics to estimate age difference. The estimation of age
difference is a subjective process, as the process of “quality estimation”. How the same metrics perform
in this new problem.

We prepared a test and we administered it to a group of persons. Since the images under analysis had
the same quality, we tried to correlate the value resulted from the metrics, to the age-difference
estimated by the humans.
The results indicate a low correlation between metrics and age-difference estimated except for CW-SSIM. A predictable result was the sensitiveness of the metrics to the particular type of transformation. This result is useful to detect different transformation applied to image.

We realized the big impact of psychological situation and sociological characteristics in human estimation.
Educational activities

Multimedia Databases
Prof. Maria Grazia Albanesi

Attendance to seminars, congresses and schools

Python programming for machine learning
Prof. Blaž Zupan and Prof. Marinka Žitnik - University of Ljubljana
Organizer: Prof. R. Bellazzi - Univ. Of Pavia Feb 2015, 18th-19th-20th

Cloud Computing
Prof. Dana Pectu - West University of Timisoara, Romania
Organizer: Prof. M. Calzarossa - University of Pavia - April 2015 28th - 29th

Seminars and presentations held

None

Stay abroad

None

List of publications

1. Poster
   IEEE Conference on Communications and Network Security (CNS 2015)
   “On the Effects of Large-Scale DNS Poisoning”,
   28- 30 September 2015 Florence - Italy
Ph.D. in Electronics, Computer Science and Electrical Engineering

Activities report a.a. 2014/15

Claudio Lenzi

XXIX Cycle

Tutor: Prof. S. Caorsi
Scientific activity:

My research activity is mainly focused on studying non-invasive time-domain EM-techniques, based on use of Artificial Neural Network, for detection and recognition of buried dielectric anomalies. The resolution of such kind of questions is connected to the resolution of an inverse electromagnetic scattering problem. Most of the resolution methods require long computation times and high computational burden because they are based on the inversion of the direct mathematical operators or on the minimization of suitable cost functionals built on the direct operators.

During these first two years of PhD, I have developed an electromagnetic technique, based on the inversion of radar data through ANNs, for breast cancer detection. The use of ANNs provides several advantages such as: short computation times, low computational burden and the opportunity of reformulate the problem by considering only a few unknowns of interest.

1. Non-invasive EM technique based on use of Artificial Neural Network for detection and recognition of breast cancer

1.a) Background:
Using 2D breast models formed by concentric layered geometries, it is possible to identify the presence of dielectric anomalies, both of high and low contrast and located at different depths from the skin surface, by simply inspecting the radargram (see Fig. 1). All the healthy tissues and the tumors have been characterized according to the Debye model using parameters provided in literature.

Figure 1. (a) an example of radargram for a 2D three-layered geometry; (b) the same radargram after the ideal cleaning operation.

As shown in Fig.1, the contribution due to the presence of the anomaly can be masked from the signal backscattered from the interface air/skin. In order to train the ANN with the most characterizing data to identify the presence of anomalies, I applied an ideal cleaning technique. At the backscattered signal measured in any angular position, I subtracted the signal measured in the same angular position but backscattered from a geometry of equal size and formed by only skin and adipose tissue.

In this contest, I trained an ANN 4-8-1 that receives 4 input data, namely the 2 amplitudes and arrival times of the first 2 maxima/minima measured on the ideally cleaned radar signals, and provides 1 output of type On/Off, depending on the presence or absence of tumor. In this ideal case the ANN is able to identify the presence of anomalies with a sensitivity equal to 100%, a specificity of 99% and an accuracy of 100%. These values have been obtained by testing the ANN with data not used for the training phase.

On the wake of these results, I started to consider more realistic models, taken from the database made
available by the *Wisconsin Computational Electromagnetics Laboratory* (UWCEM) Numerical Breast Phantom Repository. Also in this case, in order to train and test the ANN with the most characterizing data for identify the presence of anomalies, I applied an ideal cleaning technique. It consists in subtract, to the backscattered signal measured from a fixed angular position, the backscattered signal measured from the same angular position on a geometry with equal shape and dimensions but formed by only skin and adipose tissue. Moreover, since the distance between the antenna and the skin is not constant for different angular positions, I applied an equalization on times and amplitudes. For all the angular positions, the radar signal is adjusted to a unique time reference and the amplitude of the measured backscattered signal is multiplied by a coefficient that takes into account the temporal shift.

For such situations, I trained another ANN 4-8-1. It works again with the same types of 4 input data, but now referred to cleaned and equalized radar traces, and provides 1 output data (On/Off). According to the number of freedom’s degrees of the ANN 4-8-1, I trained the network with 100 training data, namely 50 measured on healthy geometries and 50 measured on geometries in which I have inserted the anomaly. For the purposes to train the ANN, I positioned the anomaly by respecting 2 constraints. The anomaly can be positioned only out from the fibroglandular tissue and with the condition that it is the first internal discontinuity that the radar signal encounters within the geometry of the breast.

First, I tested the ANN by using a test set of 100 random examples different from those used in the training phase but with the same constraints on the position of the tumor. The results showed a sensitivity equal to 86%, a specificity of 76% and an accuracy of 81%. Moreover, to test the capabilities of the ANN in a more general way, I considered 2000 new real geometries with the anomaly positioned always out from the fibroglandular tissue but without any specific constraints. In this case, the results showed a sensitivity equal to 80%, a specificity of 65% and an accuracy of 72%.

### 1.b) Optimization of the ANN 4-8-1 for the detection of Subcutaneous Tumor:

The first activity of this second year has been focused on the optimization of the ANN 4-8-1, described in the section 1, for the detection of subcutaneous tumors. To this end, on the basis of the inspection of the radar signals, I studied and selected different healthy and cancerous geometries in order to best characterize the tumor's presence. For the cancerous geometries the anomaly has been positioned always by respecting the following 2 constraints: it can be located only out from the fibroglandular tissue and with the condition that it should be the first internal discontinuity that the radar signal encounters within the geometry of the breast.

Using this geometries, I trained a new ANN 4-8-1 able to achieve, on the data used during the training phase, an accuracy of 100%. In order to assess the generalization capabilities of this new ANN, first, I tested by using the 100 random examples, also used in the section 1, built with the same constraints on the position of the tumor. The results showed a sensitivity equal to 92%, a specificity of 90% and an accuracy of 91%. At last, I tested the network with the 2000 real geometries built with the anomaly positioned always out from the fibroglandular tissue but without any specific constraints. Now, the results showed a sensitivity equal to 78%, a specificity of 79% and an accuracy of 78%.

### 1.c) Detection of tumors situated inside the Fibroglandular tissue:

As second activity, I tried to assess the performance of an ANN-based radar data processing approach also to detect the presence of tumors situated inside the fibroglandular tissue. To this end, 2000 new healthy and cancerous geometries, with the dielectric anomaly positioned inside the fibroglandular tissue, have been build.

Using the ideally cleaned and equalized radar signals, different networks, working with different data input, were trained and tested. In particular, I trained different ANNs (6-12-1, 6-12-12-1 and 6-8-1)
that receive 6 input data (namely the amplitudes and arrival times of the 3°, 4° and 5° peaks of the cleaned/equalized radar signals) and provide 1 output of type On/Off. Moreover, I trained different ANNs 4-8-1 that receive 4 input data (namely the amplitudes and arrival times of the 3° and 4° or of the 4° and 5° peaks of the cleaned/equalized radar signals) and provide 1 output (always of type On/Off). The more acceptable results have been obtained by using the ANN 6-12-1. Unfortunately, also for this best case, the results have been satisfactory only on the training data, reaching for them an accuracy of 96%, but not on the testing ones, achieving an accuracy of 62%.

1.d) Real cleaning techniques for removing the skin artifact component:
As the state of the art shows, when we deal with applications that use wideband (UWB) radar pulses for the breast cancer detection, an important issue is that the received pulses contain, besides the reflections due to the presence both of the tumor and the internal tissues, also those backscattered from the interface air/skin (the so-called artifact component). Looking at Fig.1 it is visible that the presence of the anomaly can be masked from these components. In fact, these last not only have magnitudes some orders greater than the first ones but they could be overlapped on them so as to mask the presence of the tumor. Various methods have been proposed in literature to solve this issue, but at present the problem is always open due to the difficulty to remove this artifact without introducing distortions to the tumor signature that negatively affect the diagnostic response. For these reasons, the last activities of my 2nd year of PhD have been focused on to design, assess and test new skin artifact removal techniques when applied to this novel breast cancer detection technique based on the use of Artificial Neural Network (ANN).

Each of these consists in using a different reference model (the “cleaning model”) in order to obtain the backscattered signal (the “cleaning signal”). This last is then subtracted to the total real one in order to obtain the real cleaned signal. The reference models considered consists on a bi-layered cylinder (skin and adipose tissues) characterized by suitable dielectric Debye parameters for each of these two tissues. Other important parameters for their characterization are the skin thickness, the radius dimension and the distance between the skin interface and the radar antenna. Since our detection approach is based on the ANN processing of data extracted by the cleaned radar signals, all the assessment analysis were made by comparing the amplitudes and the arrival times of the first two peaks of the same signals cleaned respectively with the ideal technique and with the real one.
First, I tried to find the best geometric/dielectric characterization and skin thickness characterizing the cleaning model. To this end, I selected and used 3 different cancerous 2D real geometries, that are significant in terms of dimensions and dielectric characterization. Considering a cleaning model made up of the same dielectric parameters and the same skin thickness of the corresponding real cases, I found its optimal dimension and position. Using such geometrical configuration, an assessment analysis has been carried by varying both the dielectric Debye parameters and the skin thickness. By this analysis I concluded that should be fundamental to know at least the thickness of the skin and the values of the static relative permittivity both of the skin and of the adipose tissue.
Finally, I analyzed the performances of different real cleaning techniques when applied to the currently studied ANN based radar cancer detection approach. To this end, I trained and tested several ANNs 4-8-1. The best results, of course, were when an ANN trained and tested with ideally cleaned radar signals is used (sensitivity 92%, specificity 90% and accuracy 91%). Nevertheless, when we apply the best real cleaning technique proposed (namely in the case we assume to know at least the real values of the \( \varepsilon_s \) of the adipose tissue, the \( \varepsilon_s \) of the skin and the skin thickness), the ANN is able to detect the presence of the anomaly with a sensitivity of 90%, a specificity of 84% and an accuracy of 87%. These good conclusions should encourage me to move on further developments, towards the study of the capabilities of a new ANN based approach able to find the real values of the \( \varepsilon_s \) of the adipose tissue, the \( \varepsilon_s \) of the skin and the skin thickness.
Education activities

Attendance to seminars, congresses and schools

1st year:

- ESoA-COST course on “Microwave Imaging and Diagnostics: Theory, Techniques, and Applications”, Madonna di Campiglio, March 24-28, 2014; (32 hours - 6.4 CFU)
- International School of Bioelectromagnetics Alessandro Chiabrera, 7th course: “Biological effects of combined exposures to EMF and other chemical and physical agents”, Erice, April 23-29, 2014; (45 hours - 9 CFU)
- III Convegno Nazionale “Interazioni tra Campi Elettromagnetici e Biosistemi”, Napoli, July 2-4, 2014; (1 presentation - 1 CFU)
- Seminar: “Radiometer broadband receivers at mm-wave frequencies”, Prof. Eduardo Artal, January 31, 2014. (0.2 CFU)

2nd year:

- Course “Imparare a progettare in Europa”. (2 CFU)
- Course “Linguaggi, problemi e metodi della comunicazione della ricerca scientifica”. (8 CFU)
- 14th Mediterranean Microwave Symposium (MMS), Marrakech, 2014. (1 presentation - 1 CFU)
- 17th International Conference on Electromagnetics in Advanced Applications (ICEAA), Torino, 2015. (1 presentation - 1 CFU)
- Seminar: “Antennas for space applications - Technologies and challenges”, Prof. Luca Salghetti Drioli, January 19, 2015. (0.2 CFU)

Seminars and presentations held

Stay abroad
List of publications

1st year:


2nd year:


Ph.D. in Electronics, Computer Science and Electrical Engineering

Activities report a.a. 2014/2015

Luca Lodola

XXIX Cycle

Tutor: prof.ssa Carla Vacchi
Scientific activity

1. Characterization of the 10 bit interleaved SAR Analog to Digital converter designed during the first year

One of the projects I am involved in is PixFEL, which is funded by INFN (Istituto Nazionale di Fisica Nucleare). The project aims at the development of an advanced pixel camera for 2D imaging applications at the next generation free electron laser (FEL) facilities. During the first year, the collaboration developed the fundamental building blocks: sensors, an analog readout channel and an analog to digital converter. A large pixel matrix (8×8), was submitted to integration last autumn together with a chip containing test structures, including the ADC alone. I have been involved in the design and test of the ADC, which is a 10 bit resolution Successive Approximation Register converter. The ADC is based on a charge redistribution architecture, implemented through a split capacitor DAC approach. Moreover, it is organized in a time-interleaved structure to speed up the ADC operation and to relax the driving capability requirements of the stage coming before the ADC. Four versions of the ADC layout have been designed and included in the test structures to experimentally evaluate which of the four is the best: with or without shields under the capacitive DAC and with or without electronic circuits under the capacitive DAC. The ADC static and dynamic performance of each of the four layout versions were evaluated at different sampling frequencies. To measure the static characteristics, the ADC input has to be fed with a quasi-DC voltage ramp. This has been achieved by means of a high linearity and low noise 16-bit DAC. The ADC output voltage and its timing are set up by a microcontroller that provides the needed configuration bits through an SPI interface. The ADC timing (start of conversion and clock signals) is set up by means of a pattern generator, synchronized with the microcontroller. The ADC output is collected by a logic analyzer each time the ADC generates the end of conversion signal and the data collected are processed by a MatLab program developed ad hoc. These measurements led to evaluating the complete ADC characteristic (output code vs Vin), the DNL (Differential Non Linearity), the INL (Integral Non Linearity), and the input noise (as the sigma of the error function fitting the probability that the ADC output exceeds a code). The ADC dynamic performance, i.e., the SNDR (Signal to Noise and Distortion Ratio), the SNR (Signal to Noise Ratio) and the ENOB (Equivalent Number of Bit), were evaluated feeding the ADC input with a full range sinusoidal signal by means of a function generator. Output codes were still collected by the logic analyzer. To perform these measurements a test board was designed, a program for the microcontroller was written, a MatLab program to process the outputs was developed and the pattern generator and the logic analyzer were set up to operate with the correct timing. The next step of the PixFEL project is to improve the design of the blocks and of the complete matrix to correct the issues detected through the experimental characterization of the prototypes (in particular problems with operation of the ADC at frequencies from 2 MHz up to design value of 5 MHz and with the integration of the front-end channel in a large scale matrix).
2. Design of a platform to evaluate the properties of the XFAB xh018 technology, in view of the design of a position sensitive detector based on the SPAD coincidence principle

Another project I am involved in is Apix2, funded by INFN, that in its first part wants to assess the feasibility of SPADs (Single Photon Avalanche Diode) with integrated electronics in the xh018 process by XFAB. A single-photon avalanche diode (SPAD) is a solid-state photodetector in which a photon-generated carrier can trigger an avalanche current due to the impact ionization mechanism. I designed the chip in the XFAB xh018 180 nm high voltage CMOS process. It includes a number of different structures:

- square SPADs, small ones (10 μm × 10 μm, 20 μm×20 μm) each with a 200 kOhm quenching resistor and provided with wire bonding pads, and large ones (100 μm × 100 μm) provided with probing pads;
- a set of test diodes (200 μm × 200 μm) with probing pads;
- an array consisting of 17 columns × 18 rows of SPADs (of three different types and dimensions) with integrated front-end electronics.

Each SPAD in the array is read out through a front-end circuit, providing a pulse with a fixed duration as a response to a signal from the sensor and interrupting the avalanche multiplication process triggered in the sensor. Three different readout channel architectures are implemented: passive quenching, active quenching and inverter based threshold crossing detection, active quenching and comparator based threshold crossing detection. Active quenching circuits can be set to four different spad-off durations (period during which the SPAD is turned off to stop the avalanche). Each cell in the array can be individually disabled. At the bottom of each column, a signal is provided consisting of the logic OR of the signals coming from all the cells in that column. A multiplexer at the bottom of the array is used to select the column output. A slow control signal is needed to configure the readout channels (output signal duration, SPAD OFF time duration, cell enable). Each channel is provided with a test terminal, enabling the test of the readout channel with an external signal.

The chip was submitted for integration and will be soon available. The SPAD and the front end electronic will be characterized in terms of: breakdown voltage, dark count rate, afterpulsing probability as a function of the dead time.
**Education activities**

1. Course "Python programming for machine learning" (2 CFU).

**Attendance to seminars, congresses and schools**

- Seminars attended (0.6 total CFU):
  1. "Advanced beamforming network using synthesized transmission lines" by Prof. Tzyh-Ghuang Ma, organized by Prof. Maurizio Bozzi.
  2. "Fundamentals of modern RF receivers" by Dr. Antonio Liscidini, organized by Prof. Rinaldo Castello.

- I attended the IEEE STARCAS course in Pavia from 2015 June 3rd to 2015 June 5th (3.6 CFU) and from 3rd to 5th September 2015 (3.6 CFU).

- I attended the VI national school “Rivelatori ed elettronica per fisica delle alte energie, astrofisica, applicazioni spaziali e fisica medica” (7.2 CFU).

**Seminars and presentations held**

I held a presentation at the international conference “IEEE Prime 2015” in Glasgow (Scotland), 2015 June 29th – July 30th, achieving the bronze best paper award. The presentation was concerned with the work "Interleaved SAR ADC for in-pixel conversion in future X-ray FEL application" (1 CFU).

I presented a poster at the international conference “Frontier detectors for frontier physics – 13th Pisa Meeting on Advanced Detectors” at La Biodola, Isola d’Elba (Italia), 2015 May 24th - 30th. The poster was concerned with the work "In-pixel conversion with a 10 bit SAR ADC for next generation X-ray FELs" (1 CFU).

**Stay abroad**

**List of publications**

Year 2014:

Year 2015:


Ph.D. in Electronics, Computer Science
and Electrical Engineering

Activities report a.a. 2014/2015

Antonio Mariano

XXIX Cycle

Tutor: Paolo Minzioni
In this second year of my PhD, my activity was dedicated to an European projects called “NISTAS”, that aims to the realization of a medical device (called “VascuLight”) for the direct and contactless measurement of the Pulse Wave Velocity in the carotid arteries. The envisioned device will be able to perform a fast and contactless measure of the Pulse Wave Velocity (PWV), i.e. of the speed at which the pressure wave propagates in the carotid, which is considered as an indicator of the arterial stiffness and of cardiovascular disease risks.

During the first part of the year, we realized a device prototype, consisting in two triangulation systems (laser-based), and we used it to measure the movement-vs-time of the carotid caused by the pressure wave simultaneously, in two different points.

My activity on this project was to collect data in collaboration with the “Fondazione IRCSS Policlinico San Matteo” and to implement an algorithm able to properly evaluate, starting from the carotid-movement curves, the time delay occurring between the passage of the same pressure impulse in two points of the carotid. Knowing this delay and the distance between the two measurement points, the PWV can be calculated and compared with the value obtained by using an Echo-tracking measurement technique.

The activity of this year was thus almost entirely dedicated to the creation and optimization of an algorithm able to extract reliable PWV data by processing the acquired “carotid-position Vs. time” signals.

After a long series of trials and verifications a final version of the algorithm was obtained, and will now be implemented in the final version of the Vasculight device.

In Fig. 1 we show the main blocks constituting the signal processing algorithm that allowed us to obtain good reproducibility results.
Fig. 1

Signals slicing and comparisons
- Split each signal width in 10 parts
- Compare each slice spectrum of one signal with each slice spectrum of the other and keep slices with maximum similarity in terms of integral

Filtering and normalization
- Signals filtering with a 3rd order low-pass Butterworth filter at 20 Hz
- Normalization to the maximum of the signal

Peak detection
- Find peak of each pulse

Second derivative and systolic foot detection
- Make the second derivative of each signals and find the systolic foot by finding the peak at the left of the time instant corresponding to the pulse peak

Delay and PWV calculation
- Delays calculation by difference of the systolic foot’s instants corresponding to the same pulse
- Calculation of a mean delay by averaging obtained values
- PWV estimation by dividing the length of the measured carotid path and the obtained mean delay
This algorithm mainly consists of two different stages.

In the first stage the two signals, constituted by a 2D matrix of values (movement as a function of transversal position and time, shown in fig 2), are divided in 10 slices each, corresponding to different transversal regions, and each slice is “averaged”, so as to remove the transverse dimension and to obtain a simple movement-time curve. After that each slice of the first signal is then compared with all the slices of the second signal, so as to obtain a measurement of the “spectral coherence” for all the 100 possible couples of slices. The spectral coherence is evaluated by using the below reported equation, where $G_{1,2}(f)$ is the cross-spectral density between the two signals and $G_{xx}(f) \ (x=1\|2)$ is the spectral density of each single signal.

$$C_{12}(f) = \frac{|G_{1,2}(f)|^2}{G_{11}(f)\ G_{22}(f)}$$

This comparison allows us to select, for the following analysis only the couple of slices (one from the first signal and one from the second one) with the higher coherence in the 0-20 Hz bandwidth, which will be used in the second stage of the algorithm.

In the second stage, the signals are filtered by a 3th order low-pass Butterworth filter at 20Hz (that is the bandwidth in which the signals lying) to remove the noise. With these clean signals, we proceed to find the peaks of the pulse wave (called “systolic pulse”) that allow us to find the starting point of each pulse (called “systolic-foot”) by watching at the left of the systolic pulse according to [1]. Once we have the time-instant at which each foot occur, we can calculate the delay between the signals by difference in time of each corresponding systolic-foot and then,
simply evaluate the PWV as $D/\Delta T$, where $D$ is the distance between the two measurement points on the neck, and $\Delta T$ the mean delay between the passage in those positions of the pressure pulses.

Encouraging results are shown in tab 1 where in green we can see values varying for less than 10% from the mean value and in yellow for less than 20%.

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<th>Patient #2</th>
<th>Patient #3</th>
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<th>Patient #5</th>
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Bibliography


Attended seminars, congresses and schools

Seminars

2. Seminar “The data transmission network of the University of Pavia: Structure and management” - 25 March 2015
4. Workshop "IEEE STARCAS " 3 - 5 June 2015
5. "Corso pratico introduttivo su LabVIEW con PXI" 8 July 2015

Schools and congress

1. PhD School "Imparare a progettare in Europa" - 10-11 e 18 February 2015
4. CLEO/Europe-EQEC Conference 2015, 21-25 June 2015, Munich, Germany

Given seminars

Seminars and presentations held

2. Presentation of the exhibit “2015 International Year of Light - La luce nel tuo presente e nel tuo futuro” and of the biophotonics research activities at “Notte dei ricercatori” – 24/09/2015

Total # of CFUs obtained as of October 9: 32.59
Ph.D. in Electronics, Computer Science and Electrical Engineering

Activities report a.a. 2014/2015

Amparito Alexandra Morales Figueroa

XXIX CICLO

Tutor: Lorenzo Favalli
Scientific activity

There are three principal activities which were developed in this year. The first one is related with the comparison of all the H.264 encoding approaches with the aim to determine which of them achieve the highest Peak-Signal-To-Noise-Ratio (PSNR). The used approaches were: Multiple Descriptions encoding - Spatial Domain (MDC-SD), Multiple Descriptions coding - Temporal Domain (MDC-TD), Scalable Video Coding with Medium Grain Scalability (SVC-MGS) and Adaptive Video Coding (AVC). This work was done using CIF (352x288) video sequences, but also, the comparison of the two MDC approaches was done to High Definition Video Sequences (1920x1088 and 1280x720).

The second activity is the implementation of a Bandwidth Estimation method based on a Hidden Markov Model. The estimation of the available bandwidth is used to provide information about the utilization of the network.

The last activity is the implementation of a Buffer Occupancy technique (DiscardPackets algorithm) with the purpose of discard in a suitable way the packets belonging to a video sequence which is being transmitted from the server. Considering the scenario in which we have a video encoded using scalable video coding (SVC-MGS), it means there are several layers with different target bit-rates, and a network which is continuously varying the bandwidth, the hierarchical discard of the packets into the buffer is a good strategy to keep the buffer just with the necessary packets to decode the video and the packets belonging to the enhancement layers to improve the quality. It is important to mention that the output of the Bandwidth Estimation method is used as an input in the current algorithm.

The three activities aforementioned are explained in detail below.

1. Comparison of the H.264 Encoding approaches

Before to select a specific H.264 encoding approach is crucial to analyze and define the scenario. For instance, if we have a network where the bit-rate is constant, we could encode the video sequence using AVC with a suitable Quantization Parameter (QP) value to achieve the available bit-rate. Furthermore, if the bandwidth fluctuates in the time, it will be better to use SVC or Multiple Descriptions Coding with MGS.
In this work, we assuming no packet losses, but in real scenarios this aspect should be considered. In this case, if MDC is used and some packets belonging to one description stream are lost, these could be compensated with the packets of the second received description. On the other hand, if SVC is employed and packet losses take place, it would not be possible to recover these packets and consequently the PSNR would be decreased.

Considering no packet losses and calculating the PSNR to the maximum bit-rate achieved by the encoder, the best PSNR value is obtained with the Scalable Video Coding (SVC-MGS). But, it is closely followed by the MDC-TD when both descriptions are received.

On the other hand, when the two MDC approaches (MDC-TD and MDC-SD) were used to encode ten HD video sequences, the obtained results shown that when just one description is received in the receiver side, the two approaches give a similar PSNR. However, when both descriptions are received, a higher PSNR is obtained with the MDC-TD approach. The PSNR is increased around 2 dB compared with the MDC-SD approach.

2. Bandwidth Estimation Model using Hidden Markov Model

![One-step transition Markov chain](image)

The available bandwidth in an end-to-end path can be modeled by $N$ states each one representing certain level of availability. For example, Figure 1 shows a five-state representation where the AB could be in one of Low(L), Medium Low (ML), Medium (M), Medium High (MH) and High (H)
states. Therefore, One-step transition Markov chain can be used to estimate the probability of being in a particular estate or available bandwidth (AB) range. As the available bandwidth can not be directly observed, the AB estimators sample the network path with probe packets. So, this information can be used by the Hidden Markov Model to infer the non-observable state.

Figure 2 presents, in a synthetic way, the elements of the HMM. Where A is the transition probability, B is the probability of being in a hidden state from a particular sample, X is a state, and $\xi$ represents an observation symbol (probing packet).

![Figure 2: Hidden Markov Model](image)

With the purpose of analyze the model and its accuracy some experiments changing the values of matrix A and B were done. It is important to keep in mind that the outputs delivered by the HMM are the symbol sequence and the state sequence, both outputs generated by the model.

In the first experiment we change the A matrix values. This matrix can be constructed using random or equally likely values. In both cases, we obtained similar results because the initial A matrix is constructed based in guesses, because we do not use the really state transition probability values. Then, it is possible construct the initial A matrix (one-step transition) in a random way without change the final result.
The second experiment was to change the B matrix. The observation probabilities matrix (B) is a set of probabilities that indicates how likely it is that at time $t$ an observation symbol $S_t$ is generated by each state. This matrix is constructed regarding that the small values of $\xi$ are the result of a no loaded network and therefore more likely generated by a high order state (indicating a high available bandwidth) and conversely.

When the number of symbols is equal to the number of states, each symbol can be assigned to one state. Hence, exist a equitable distribution of the symbols occurrence probabilities. By the other hand, when the number of symbols is less or greater than the number of states is not possible to do the process mentioned above and other concept is adopted. The idea is distribute, in a balanced way, the symbols in the states. In this way, the symbols corresponding to a high delay are more likely to appear in the low states and vice versa. Another way to construct the B matrix is generating the values randomly or giving the same probability to all the symbols in each state.

When we use a B matrix randomly generated, the symbol sequence constructed by the model is similar to the initial one but the state sequence drastically varies. The reason is because the B matrix, does not follow any specific behavior, it is random.

Furthermore, the states sequence obtained using the Bandwidth Estimation is used as an input in the Buffer Occupancy algorithm, which is described below.

### 3. Buffer Occupancy

The Buffer Occupancy algorithm is developed considering the scenario shown in Figure 3, where a video sequence is encoded using Scalable Video Coding (SVC) and Medium Grain Scalability. This configuration was selected because is more flexible and permit to have more rate points in one stream. The video was encoded using the H.264 JSVM encoder.

After the video is encoded, the trace file is generated using the BitStreamExtractor tool included in the JSVM software. This trace file is a text file, which specifies various parameters for each single “packet” inside the given bit-stream. These parameters include the start position (in units of bytes)
of the packet inside the bit-stream, the length of the packet (in units of bytes), the values of dependency_id (LId), temporal_level (TId), and quality_level (QId) for the packet, the type of the packet, and two flag which indicate whether the packet is discardable or truncatable.

The next step, is to calculate the time when the packets arrive to the buffer and the time in which this packets leave the buffer. These times are obtained dividing the packet size to the respective bit rate. To found the first time, we use the download rate, that in this case is fixed and equal to the maximum bit rate to the video was encoded. Moreover, to calculate the second time, we use the playout rate, which is varying each second of time. Also, the values of the playout rate are obtained using the Bandwidth Estimation method implemented in 2.

![Figure 3: Scenario to the DiscardPackets Algorithm](image)
We set up the buffer to a large size and, also a threshold value is defined. This threshold is less than the total buffer size. When this threshold is attained, it means that the buffer is close to the risk of overflowing and some strategy to discard packets must be taken. and start the transmission of the packets from the server to the buffer. The packets leave the buffer following the FIFO policy. In that case, if the playout rate is lower than the download rate, at some point the buffer threshold is attained and the DiscardPackets algorithm is applied.

Regarding we are using a video which was encoded using SVC-MGS, with one base layer and three enhancement layers. All of the last ones have 2 MGS Vectors, it means each enhancement layer owns two rate points each one. It gives us a total of seven rate points. Moreover, Scalable video coding defines a hierarchical model, it is that the highest layers depends to the lower layers. In that way, the packets belonging to the base layer can not be discarded for any reason because if these packets are missing will be impossible deconding the video.

Some constrains have to be considered at the moment to discard a packet, and these are presented below:

- The packets belonging to the highest layers have to be discarded first than the others.

- When SVC-MGS is used, each enhancement layer present different qualities each one. Layer three has packets with QId equal to 6 and 5, layer two has packets with QId equal to 4 and 3 and layer 1 has packets with QId equal to 2 and 1. As the same way, the packets are discarded from the highest QId.

- The video encoded presents four different temporal levels (TId). These temporal levels, also, own a hierarchical dependency. So, the packets with the highest TId will be discarded first.

- The packets are discarded until attain a defined threshold, it means not all the packets which are in the buffer are discarded, just a percentage of them. This percentage can be set up to 10, 20 or 50 percent, depending the application.

- When a packet is discarded, all the packets which depend of this packet, must to be discarded too. All the packets with the same (Lid,Tid,QId) than the discarded packet must to be discarded. Also,
the packets of all the up layers from the discarded packet must to discarded.

- After a packet has been discarded, also the packets which are arriving to the buffer are controlled. If the arrived packet depends of some discarded packet before, it is discarded. In this way, the occupancy of an unnecessary packet into the buffer is avoided.

- At the end, the output trace file, the file which will be decoded, is controlled one more time. This post processing step is done because some dependent packets could have been written into the output file before the DiscardPackets algorithm take place.

The pseudocode of the DiscardPackets algorithm is presented in Algorithm 1.
Algorithm 1: DiscardPackets

For all packets into the Buffer {
/* Discard packets from the highest layer, starting from packets to Layer 3, Layer 2 and finally Layer 1 */
Store the packets considering the QId;

If (packetsQId 6 ≠ Empty) {
/* Start discarding from the highest temporal level*/

If (Tid == 3)
Discard all packets Tid = 3;

else if (Tid == 2)
Discard all packets Tid = 2;

else if (Tid == 1)
Discard all packets Tid = 1;

else
Discard all packets Tid = 0
}

If (nDiscardedPackets < threshold) {

If (packetsQId 5 ≠ Empty)
Discard packets considering the temporal level;

}
continue doing the same process until nDiscardPackets is greater or equal to the threshold.
}
**Education activities**

None

**Attendance to seminars, congresses and schools**

<table>
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<tr>
<th>Type</th>
<th>Title</th>
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| Course    | “Linguaggi, problemi metodi della comunicazione della ricerca scientifica”  
            | Collegio Nuovo-Fondazione e dalla SAFD dell'Università degli studi di Pavia. |
| Seminar   | “Three core issues for the Internet: things, security and economics”  
            | Prof. Henning Schulzrinne                                               |

**Seminars and presentations held**

**Stay abroad**

**List of publications**
Ph.D. in Electronics, Computer Science and Electrical Engineering

Activities report a.a. 2014/2015

Marcel Pendieu Kwaye

XXIX Cycle

Tutor: prof. Norma Anglani
**Scientific activity**

**Topic 1: Review paper on hybrid energy systems (HES)**

A literature review on hybrid energy systems has been carried out last year and has been completed this current year. The objective of this activity: (i) to have a good knowledge of the status of ongoing research in field and (ii) to have an overview on different types of HES and theirs different applications, including the role of storage. The study clearly identified: (i) the variation of type of hybrid micro-grids including isolate house, a community of isolated houses, a village, a city only for name these (ii) the important role of storage system in remote electrification areas, (iii) the influence of geographical position on different type of hybrid generating system combined with storage system.


**Topic 2: Assessment of Renewable Energy Resources in Cameroon.**

Because it was not possible to rely on data (solar radiation and wind speed) coming from a proper network of surface observation stations for collecting weather data in Cameroon, it was chosen to look for such data by the means of software such as Solargis, Nasa, Swera, Nrel, ...

The scope of this work was: (i) focus on assessment of two different Energy resources (solar and wind), (ii) understand how to determine the potential of solar radiation and wind energy across the country, (iii) determine which region is good enough to conduct a case study.

The research concerns all the ten regions that make up Cameroon. NASA (surface meteorological and solar energy) database have been used for assessment by introducing the geographical coordinate of any regions and obtaining the daily solar radiation and the average means wind speed for every month of the year.

This particular study concluded that not only the Northern regions of Cameroon have the highest wind potential, but also the North West and some towns in the other regions.

The study also concluded that the fact of having enormous potential of solar energy
can contributed to electrify remote villages across the country and contribute to better life and prosperity.

While these results reflect the general trend, it is important to conduct field studies in substantial number of places in order to further estimate with accuracy the potentials of wind energy in Cameroon.

In the same goal, the following topics have been prepared in different parts for the future case study for the final thesis.

**Model of Weibull distribution for wind speed and simulations.**

It is the Probability distribution function, used to describe the distribution of wind speed over an extended period.

A code function of the Weibull distribution has been written for describing the wind distribution over a set period.

The particularity of this code is that the scale parameter of the Weibull function [m/s] and the Shape parameter of Weibull function can be automatically calculated and visualized.

Simulations have been done to test the performance of the code.

**Some Power curve of some wind generator**

Characteristics of some wind generator machine such as: AN_150_450_600_1000kW; Enercon_E33_E40_E66_300_500_1500kW; Nordex_Dewal_N29_N52_N54_150_250_1000_1000kW; Tracke_Tw60_Tw80_Tw300_Tw600_Tw600e_Tw1500kW; Vertas_V44_V47_V66_600_660_1500kW have been retrieved, used and plot in Matlab to check the behavior of commercial generator in order to be selected for the project.

**Implementation of a wind generator**

A model of wind generator has been implemented in Matlab as a component of a whole system that have to be put in place with the aim of using it for simulating the wind generator selected and see his behavior during all the running time.

**Implementation of an Inverter**

A model of a PWM generator has been sketched but still the full implementation has to be accomplished.

**Homer software**

The Hybrid Optimization Model for Renewable Energy software (HOMER) has been identified for the feasibility study.

This software could help to design and optimize the micro-grids and verify its techno-economic feasibility.

This software can help to model micro-grids for cost-effective and reliability that combine traditional generators with renewable power, storage and also load
management. Some simple examples have been tested with good result. The next step is to use HOMER on the real case study, by using real data.


**Topic 3: Use of Hydro Power for Fluctuation Compensation in Cameroon.**
Cameroon possesses the second largest hydro power potential in Central Africa. Electricity is distributed all over the country by three separate transmission grids, isolated one to the another without any way of exchanging surplus of electricity between them.

The aim of the study was: (i) to explore the potential of wind and solar energy (ii) identified river that can be hugely exploited for hydroelectricity production and (iii) to see how hydropower can contribute for fluctuation compensation in case of unavailability of wind or solar energy.

A draft of solar and wind potential profile has been build up, with the difficulty of having a good smooth profile of wind and solar energy potential for a whole year. Because of lack in real data, the smoothness of the profile was not so good and must be improved, likely, in the very next future.

**Education activities**

Solar Electric Energy System (06 credits are expected to be acknowledged) has been successful done in Germany, at the University of Pavia it corresponds to Impianto solare e impianti a biomasse (06 credits).
The course of Advanced mathematical methods for Engineers, planned in the first Erasmus activity plan, has been replaced by the above course because was focused mainly on Electromagnetism mathematic models, while the other course was specific on renewable energy, acquisition data from weather station, Irradiance potential, solar thermal, Inverter, Mounting, Storage and optimization.

**Attendance to seminars, congresses and schools**

3 seminars (without acknowledgment of credits):
- “Implementation and Simulation of Pulse Width Regulated Series-Parallel Resonant Converter”, held by M.Sc Lin Jing. (Paderborn – LEA - 23/10/2014)
- “Modeling the Losses in Automotive Traction Drives Using Permanent-Magnet Synchronous Motor with Buried Magnets”, held by M.Sc Elisabeth Lutzelberger.

**Seminars and presentations held**

The paper “Hybrid Energy System for Remote Areas and the Role of Storage” was presented at the IEEE International Conference on Industrial Technology (ICIT) 2015, Sevilla, Spain (01 credit are expected to be acknowledged).

The paper “Assessment of Renewable Energy Resources in Cameroon and Special Regards on Energy Supply” at the IEEE 5th International Youth Conference on Energy (IYCE) 2015, Pisa, Italy (01 credit are expected to be acknowledged).

The Paper “Assessment of Renewable Energy Resources and the use of Hydro Power for Fluctuation Compensation in Cameroon” at the IEEE 5th International Youth Conference on Energy (IYCE) 2015, Pisa, Italy (01 credit are expected to be acknowledged).
Stay abroad

I have been hosted under the Power Electronics and Electrical Drive Engineering (LEA) held by Prof. Dr.-Ing Joachim Boecker and the research group of Sustainable Energy Concepts (NEK) held by Prof. Dr.-Ing Stefan Krauter for 10 months (November 2014-September 2015) under the Erasmus program flag at the university of Paderborn (Germany).

All my activities carried out in Paderborn was under the Sustainable Energy Concepts (NEK) research group held by Prof. Dr.-Ing Stefan Krauter. Some activities, previously agreed with my tutor, such as: Acquire deep knowledge in Electronics, acquire knowledge in simulations using matlab/simulink, realize practical simulations on test bench have not been carried out under the department of Power Electronics and Electrical Drive Engineering (LEA) because of mismatching time table with the research group's activities, nonetheless they have been replaced the mentioned activities on topics (2) and (3).

List of publications

First Year: 2013-2014


Second Year: 2014-2015


Ph.D. in Electronics, Computer Science and Electrical Engineering

Activities report a.a. 2014/2015

Andreas Salentinig

XXIX Cycle

Tutor: Paolo Gamba
Scientific activity

The second year of the PhD program was mainly dedicated to the development, application and evaluation of Synthetic Aperture Radar (SAR) fusion methods for the purpose of urban area extraction. The research was conducted within the framework of the ESA DRAGON 3 project as well as in the ESA Climate Change Initiative – Land Cover (CCI-LC) project. During the past academic year I was able to gather a deeper understanding of urban remote sensing in general, and especially in the exploitation of SAR data sets for the purpose of urban area extraction. Furthermore my IDL and Matlab programming skills as well as my remote sensing skills with respect to image processing, data fusion and accuracy assessment have been tremendously improved. These achievements represent a fundamental milestone on the path to the overall goal of my PhD project “Human settlement characterization at the global scale by fusing SAR and multispectral data sets at multiple spatial resolutions”.

A description of the research projects, their missions and the ongoing activities will be presented in the following paragraphs.

1. “DRAGON 3” project

The Dragon 3 Program funded by the European Space Agency and (ESA) and Ministry of Science and Technology of the People’s Republic of China (MOST) selected one of the projects to monitor urbanization in China using multi-scale and multi-source data. The overall objective of the research carried out by the partners of this project (the University of Pavia, the Royal technological Institute in Sweden, the German Aerospace Center, the China University of Mining and Technology and the Tsingshua University in China) is to investigate multi-temporal, multi-scale and multi-sensor data for analysis of urbanization and climate impact in China for sustainable urban development.

As mentioned above, during the second year I focused on the detection of urban areas in SAR data sets and the fusion of SAR data sets, coming from different sensor with specific data characteristics. Our contributions to the project can be summed up as follows:

- Development/application of SAR data fusion methods
  - Multi-scale Kalman filter based approach
  - Fusion method based on histogram matching and image weighting
- Generation of precise reference data for several areas in China and Brazil
- Validation of fusion results for testsites
- Summary, comparison and evaluation of all developed fusion methods (five in total) in a journal paper
- Review of SAR and optical fusion approaches in the context of global urban extraction, published in journal paper.

1. “CCI-LANDCOVER” project

The goal of ESAs Climate Change Initiative is to provide stable, long-term, satellite-based Essential Climate Variable (ECV) data products for climate modellers and researchers. The CCI is bringing together European expertise covering the full range of scientific, technical and
development specializations available within the European Earth Observation community and will establish lasting and transparent access for global climate scientific and operational communities to its results. Within this framework the CCI-LANDCOVER project is responsible for the generation of global landcover maps, global landcover seasonality products and global water bodies product. The contributions of our research group to this project can be summed up as follows:

- Adaption and optimization of an already existing urban area extraction algorithm (UEXT) for the application on Sentinel 1 SAR data
- Generation of reference data sets for testsites in Tunisia, Portugal, Egypt, Israel and Turkey

**Education activities**

- None

**Attendance to seminars, congresses and schools**

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<tr>
<th>Title</th>
<th>Course</th>
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<tbody>
<tr>
<td>Linguaggi, problemi metodi della comunicazione in ricerca scientifica, Collegio Nuovo, Pavia</td>
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<td>Data fusion for risk mapping, July 2015, Pavia</td>
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<td>Cloud Computing, April 2015, Pavia</td>
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<td>ESA Dragon 3 Symposium, June 2015, Interlaken, Switzerland</td>
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<td>JURSE 2015, Lausanne, Switzerland</td>
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**Seminars and presentations held**

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<tr>
<td>Fusing Coarse And Medium Resolution SAR Data For An Improved Detection Of Built-up Areas, oral presentation, ESA Dragon 3 Symposium, 24/06/2015, Interlaken, Switzerland</td>
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**Stay abroad**

- 08/2014 – 02/2015: PUC Rio de Janeiro, Brazil
- 06/2015: Friedrich Schiller University Jena, Germany
List of publications

International Journal papers


Conference proceedings

1. A. Salentinig, and P. Gamba, “Fusing Coarse And Medium Resolution SAR Data For An Improved Detection Of Built-up Areas” ESA Dragon 3 Symposium, Interlaken, Switzerland, June 2015

Conference posters

1. A. Salentinig, and P. Gamba, “A fuzzy fusion approach for improved urban area detection in multi-resolution SAR data”, Poster, JURSE 2015, 31/03/2015, Lausanne, Switzerland

2. A. Salentinig, and P. Gamba, “Fusing ASAR Wide Swath Mode (WSM) And Image Mode Precision (IMP) Data Based On Histogram Matching And Image Weighting For The Purpose Of Built-up Area Detection”, Poster, ESA Dragon 3 Symposium, 24/06/2015, Interlaken, Switzerland
Modeling and Control of Lithium-ion batteries
Ph.D. in Electronics, Computer Science
and Electrical Engineering

Activities report a.y. 2014/2015

Marcello Torchio
XXIX Cycle

Tutor: Lalo Magni
**Scientific activity**

The penetration of renewable sources in power networks as well as the increasing demand for portable devices (e.g., smart-phones) and hybrid electric vehicles (HEVs) calls for the design and management of storage devices of high power density and reduced size and weight. During the years different chemistries of batteries have been developed, such as Nickel Cadmium (NiCd), Nickel Metal Hybrid (NiMH), Lead Acid and Lithium ion (Li-ion) and Lithium ion Polymer (Li-Poly). Among electrochemical accumulators, Li-ion batteries provide the best trade-off in terms of power density, low weight, cell voltage, and low self-discharge.

Mathematical models can support the design of new batteries as well as the development of new Advanced Battery Management Systems (ABMS). According to literature, two main categories of mathematical models can be used to represent Li-ion battery dynamics: the Equivalent Circuit Models (ECMs) and the Electrochemical Models (EMs). ECMs rely their formulation on the usage of resistors, capacitors and voltage sources to represent the dynamics of a Li-ion battery. On the other side EMs, exploit electrochemical and physical models to represent the battery dynamics.

Even if the ECMs would be preferable due to their simplicity, EMs are more accurate since able to describe detailed physical phenomena. The most widely used EM in the literature is the porous electrode theory-based pseudo-two-dimensional (P2D) model, which is described by a set of tightly coupled and highly nonlinear partial differential-algebraic equations (PDAEs) [DOYLE1]. EMs can be used to accurately estimate indices of particular interest related to the State of Charge (SOC) or the State of Health (SOH). The SOC is an important property of batteries because it quantifies the amount of charge remaining.

For Li-ion batteries, the bulk SOC within an electrode can be defined as the spatial integral over the electrode length of the ratio between the instantaneous lithium concentration and the maximum saturation concentration. The knowledge of the SOC can be used to prevent damage, ensure safety, and minimize charging time [GOPA01].

The SOH index measures the ability of the battery to store and deliver electrical energy; similarly to the SOC, estimation based approaches are used to predict the value of the SOH. The SOH tracks the long term changes in a battery and its knowledge can help ABMS
systems to anticipate problems through online fault diagnosis while providing charging profiles able to slow down the battery aging. In order to exploit this physicochemical information into ABMS, the set of equations describing the EMs need to be reformulated as a set of ordinary Differential-Algebraic Equations (DAEs). The model reformulation is very challenging to carry out in a way that is simultaneously computationally efficient and numerically stable for a wide range of battery parameters and operating conditions.

My research was devoted to develop a freely available MATLAB framework able to simulate the P2D EM for Li-ion batteries. The development has interested the adoption of a numerical scheme named Finite Volume Method to ensure physical meaningful of the obtained solutions. Numerical implementation of the P2D model is challenging due to the presence of highly non-linear and coupled equations, as well as boundary conditions which concurs in the obtainment of physical meaningful solutions. According to its formulation, FVM has conservative properties which make it a suitable numerical algorithm for these types of models [PAT01]. The framework has therefore been used as a tool for the application of several control algorithms with different objective.

Sensitivity-based control has been implemented in order to derive a predictive control algorithm based on a Linear Time Varying (LTV) representation of the battery. In this particular case a LTV Finite Step Response (LTV-FSR) model has been developed around a nominal trajectory. Such trajectories have been obtained by performing an offline non-linear optimization over a given grid. Such optimization had the objective to drive the battery to a given SOC, while enforcing physical constraints on temperature, voltage, SOC and input current. Optimization procedures have been run with respect to several initial states, thus satisfying different possible initial conditions from which the battery could start. According to the estimate of the initial conditions, the ABMS will adopt the nearest set of nominal trajectories and will perform the optimal charging process while rejecting possible disturbances through the presence of a feedback control.

Health-aware control algorithms are under development. In this case the aging dynamics of the Li-ion battery are incorporated into the set of original model equations. These dynamics model the growth of the so-called Solid-Electrolyte Interface (SEI). In literature it is well
known that the SEI is mainly due to side reactions caused by oxidation or reduction of solvents at the interface between anodes or/and cathodes with the electrolyte solution. Even if its formation during the first charges is inherently due to the physicochemical phenomena inside the battery, its thickness continues to increase during the future charging cycles [ARORA01]. As a consequence an additional voltage drop will be present due to the increasing internal impedance. Besides the formation of the SEI layer, capacity fade phenomena occurs with the aging of a battery; indeed this phenomenon is responsible to reduce the capacity of the battery by shortening the time required to fully discharge the cell [RAMADA01].

The health-aware control algorithms are therefore able to provide an optimal charging profile, with the aim to minimize the effect of capacity fading over a certain number of charging cycles while ensuring a proper SOC tracking. In particular, an estimate of the loss of capacity is made at the end of each charging cycle and the states of the battery are updated accordingly. By considering the effect of capacity fading, predictive controllers can exploit such information and synthesize a control action which tries to minimize the evolution of capacity fade effects.

Bibliografia

DOYLE1: T.F. Fuller, M. Doyle and J. Newman, Simulation and optimization of the dual lithium ion insertion cell, 1994
PAT01: S. Patankar, Numerical heat transfer and fluid flow, 1980
ARORA01: P. Arora, R. E. White and M. Doyle, Capacity fade mechanisms and side reactions in lithium-ion batteries, 1998
RAMADA01: P. Ramadass, B. Haran, P.M. Gomadam, R. White and B.N. Popov, Development of first principles capacity fade model for Li-ion cells, 2004
**Education activities**

I attended to the Bertinoro Ph.D school about the topics of “Robotics” and “Underwater Robotics” in July 2015. I took the exam of “Impianti Eolici” (Wind Power Plants) at the University of Pavia during the second semester. I have been teaching assistant for the course “Fondamenti di Automatica” (Automatic Control) with Professor Giancarlo Ferrari Trecate during the academic year 2014/2015.

**Attendance to seminars, congresses and schools**

2\textsuperscript{nd} - 5\textsuperscript{th} July 2015: American Control Conference – Chicago
13\textsuperscript{th} - 18\textsuperscript{th} July 2015: Ph.D School in Bertinoro about Robotics and Underwater Robotics
14\textsuperscript{th} - 16\textsuperscript{th} September 2015 : Ph.D short course about the LMI/BMI approach to optimal control.
29\textsuperscript{th} – 30\textsuperscript{th} September 2015 : Ph.D short course about Electrical machines for advanced applications

**Seminars and presentations held**

I held two talks at the American Control Conference in Chicago (July 2015) to present two different accepted works. The two talks were about optimal placement of storage devices along a power network with renewable penetration and the optimal charging of Li-ion batteries.

**Stay abroad**

I have been abroad for 5 months (from 1\textsuperscript{st} of November 2014, to 25\textsuperscript{th} of March 2015) in Cambridge (MA), United States of America. I was at the Massachusetts Institute of Technology (MIT) in the Chemical Engineering Department, supervised by Professor Richard D. Braatz working about the topic of modeling and control of Li-ion batteries.
List of publications

