
**PhD in Information Technology and Electrical Engineering**

**Università degli Studi di Napoli Federico II**

# PhD Student: Massimiliano Gargiulo

**XXXIII Cycle**

**Training and Research Activities Report – Third Year**

**Tutor: Giuseppe Ruello**

1. Information

Massimiliano Gargiulo, Master Degree in Telecommunication Engineering – University of Naples "Federico II"

XXXIII Cycle - ITEE - Università di Napoli Federico II

Tutor: Prof. Giuseppe Ruello

2. Study and Training activities

During my first year of the PhD I have taken the following courses:

- ✓ Ad Hoc: Matlab Fundamentals
  Lecturer: Dott. Stefano Marrone
  Period: February-March

- ✓ Ad Hoc: PROFESSIONAL SKILLS IN CLINICAL ENVIRONMENT FOR BIOMEDICAL ENGINEERING
  Period: November-December
  Lecturer: Prof. Ing. Giovanni D'Addio.

- ✓ Ad Hoc: Innovation management, entrepreneurship and intellectual property
  Period: September-October
  Prof : Pierluigi Rippa.

and I have attended the following seminars:

- ✓ Title: Computational Biology: Large scale data analysis to understand the molecular bases of human diseases (Credits: 0.2)
  Lecturer: Prof. Michele Ceccarelli
  Date: April 4th, 2020

- ✓ Title: How to Get Published with IEEE (Credits: 0.4)
  Lecturer: Eszter Lukacs
  Date: April, 20th 2020
  Title: SAS Analytics

Lecturer: Dr Cinzia Gianfiori.
Date: 14th May 2020 (Credits: 0.4)

✓ Title: Telemedicina in Italia: casi di successo (Credits: 0.6)
Organizer: Prof. Ing. Giovanni D'Addio
Lecturer: Dott. Maurizio Nardi
Date: November 17th, 2020

✓ Title: Campi elettromagnetici pulsati: dal meccanismo d'azione alle applicazioni cliniche
Lecturer: Simona Salati.
Organizer: Prof. Rita Massa, Prof. Giuseppe Ruello.
Date: 15th May 2020 (Credits: 0.3)

✓ Title: Sensing
Lecturers: Jerome Wenger, Carsten Rockstunhl, Leonetta Baldassarre, Monika Fleischer.Organized by the SIOF working group Plasmonic & Nano-Optics.
Date: 20th May 2020 (Credits: 0.8)

✓ Title: Applicazioni mediche dei campi elettromagnetici basate sull'incremento di temperatura: ipertermia e ablazione.
Lecturer: Marta Cavagnano.
Organizer : Prof. Rita Massa, Prof.Giuseppe Ruello.
Date 22th May 2020 (Credits: 0.3).

✓ Title: Non invasive Mapping of Electrical Properties using MRI.
Lecturer: Riccardo Lattanzi
Organizer: Prof. Rita Massa, Prof. Giuseppe Ruello.
Date: 11th June 2020 (Credits: 0.3)

In the following table is depicted a summary of the activities presented above:

| Student: Massimiliano Gargiulo<br>massimiliano.gargiulo@unina.it | | | | | | | | | Tutor: Giuseppe Ruello<br>giuseppe.ruello@unina.it | | | | | | | | Cycle XXXIII | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Credits year 1 | | | | | | | | Credits year 2 | | | | | | | | Credits year 3 | | | | | | | | | |
| | Estimated | 1 bimonth | 2 bimonth | 3 bimonth | 4 bimonth | 5 bimonth | 6 bimonth | Summary | Estimated | 1 bimonth | 2 bimonth | 3 bimonth | 4 bimonth | 5 bimonth | 6 bimonth | Summary | Estimated | 1 bimonth | 2 bimonth | 3 bimonth | 4 bimonth | 5 bimonth | 6 bimonth | Summary | Total | Check |
| Modules | 18 | 0 | 0 | 6 | 0 | 3 | 12 | 21 | 9 | 0 | 0 | 7 | 0 | 0 | 0 | 7 | 9 | 0 | 2 | 5 | 0 | 0 | 2 | 9 | 37 | 30-70 |
| Seminars | 13 | 0.8 | 0 | 1.3 | 0 | 2 | 1.1 | 5.2 | 6 | 0.2 | 0 | 1 | 0 | 3.6 | 1.2 | 6 | 6 | 0.3 | 0.6 | 2.1 | 0 | 0 | 0.6 | 3.6 | 14.8 | 10-30 |
| Research | 34 | 9.2 | 10 | 2.7 | 7 | 5.1 | 0 | 34 | 42 | 9.8 | 10 | 2 | 10 | 6.4 | 8.8 | 47 | 42 | 9.7 | 7.8 | 2.9 | 10 | 10 | 7.4 | 47.8 | 128.8 | 80-140 |
| | 65 | 10 | 10 | 10 | 7 | 10.1 | 13.1 | 60.2 | 57 | 10 | 10 | 10 | 10 | 10 | 10 | 60 | 57 | 10 | 10.4 | 10 | 10 | 10 | 10 | 60.4 | 180.6 | 180 |

3. Research activity

In the three years of my PhD I focused the research activity on two main topics:

a. Deep Learning approaches in specific Remote Sensing Applications
b. 5G Channel Modeling in an urban environment

Here I briefly explain each of which:

The first research topic is designing and implementing a deep learning framework applied to remote sensing. Remote sensing techniques and applications play a crucial role in observing the Earth evolution, especially nowadays, where the effects of climate change on our life is more and more evident.
A considerable amount of data are daily acquired all over the Earth. Effective exploitation of this information requires the robustness, velocity and accuracy of deep learning. This emerging need inspired the choice of this topic.

The conducted studies mainly focus on two European Space Agency (ESA) missions: Sentinel 1 and Sentinel 2. Images provided by the ESA Sentinel-2 mission are rapidly becoming the main source of information for the entire remote sensing community, thanks to their unprecedented combination of spatial, spectral and temporal resolution, as well as their open access policy. The increasing interest gained by these satellites in the research laboratory and applicative scenarios pushed us to utilize them in the considered framework. The combined use of Sentinel 1 and Sentinel 2 is crucial and very prominent in different contexts and different kinds of monitoring when the growing (or changing) dynamics are very rapid.

Starting from this general framework, two specific research activities were identified and investigated, leading to the results presented in this dissertation. Both these studies can be placed in the context of data fusion.

The first activity deals with a super-resolution framework to improve Sentinel 2 bands supplied at 20 meters up to 10 meters. Increasing the spatial resolution of these bands is of great interest in many remote sensing applications, particularly in monitoring vegetation, rivers, forests, and so on.

The second topic of the deep learning framework has been applied to the multispectral Normalized Difference Vegetation Index (NDVI) extraction, and the semantic segmentation obtained fusing Sentinel 1 and S2 data. The S1 SAR data is of great importance for the quantity of information extracted in the context of monitoring wetlands, rivers and forests, and many other contexts.

In both cases, the problem was addressed with deep learning techniques, and in both cases, very lean architectures were used, demonstrating that even without the availability of computing power, it is possible to obtain high-level results.
The core of this framework is a Convolutional Neural Network (CNN). CNNs have been successfully applied to many image processing problems, like super-resolution [1], pansharpening [2], classification [7], and others, because of several advantages such as (i) the capability to approximate complex non-linear functions, (ii) the ease of training that allows to avoid time-consuming handcraft filter design, (iii) the parallel computational architecture.
Even if a large amount of "labelled" data is required for training, the CNN performances pushed me to this architectural choice.

To reach this aim, the following references have been mainly considered and studied:

[1] Chao Dong, Chen Change Loy, Kaiming He, and Xiaoou Tang,"Image super-resolution using deep convolutional networks, "IEEE transactions on pattern analysis and machine intelligence, vol. 38, no. 2, pp. 295–307, 2016.
[2] Junfeng Yang, Xueyang Fu, Yuwen Hu, Yue Huang, XinghaoDing, and John Paisley, "Pannet: A deep network architecture for pan-sharpening," pp. 5449–5457, 2017.
[3] Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun, "Deep residual learning for image recognition," pp. 770–778,2016.
[4] Charis Lanaras, Joše Bioucas-Dias, Silvano Galliani, Emmanuel Baltsavias, and Konrad Schindler, "Super-resolution of Sentinel-2 images: Learning a globally applicable deep neural network," arXiv preprint arXiv:1803.04271, 2018.
[5] S. t. Wu and S. A. Sader, "Multipolarization SAR data for surface feature delineation and forest vegetation characterization," IEEE Trans. Geosci. Remote Sens., vol. GE-25, no. 1,pp. 67–76, 1987.
[6] Tianxiang Zhang, Jinya Su, Cunjia Liu, Wen-Hua Chen, Hui Liu, and Guohai Liu, "Band selection in Sentinel-2 satellite for agriculture applications," in Automation and Computing(ICAC), 2017 23rd International Conference on. IEEE, 2017, pp. 1–6.
[7] Y. Du, Y. Zhang, F. Ling, Q. Wang, W. Li, and X. Li, "Water bodies mapping from sentinel-2 imagery with modified normalized difference water index at 10-m spatial resolution produced by sharpening the SWIR band, "Remote Sensing, vol. 8, no. 4, pp. 354, 2016.
[8] Donato Amitrano, Gerardo Di Martino, Antonio Iodice, Daniele Riccio, and Giuseppe Ruello, "Unsupervised rapid flood mapping using Sentinel-1 GRD SAR images," IEEE Transactions on Geoscience and Remote Sensing, vol. 56, no. 6, pp.3290–3299, 2018.

The second research topic is related to the mm-Waves that have been identified as a promising technology since higher data rate, lower latency and lower power consumption than 4G technology are achieved. However, the bottleneck of the use of such high frequencies is related to attenuation and penetration through buildings to allow outdoor-indoor communications. Therefore, it is important to provide a complete characterization of the wireless channel to the above-mentioned transmission frequencies. This research activity has been carried out in several phases. Furthermore, it is crucial a proper design of the antenna patterns in the 5G context because of its requirements. In the first phase, the classical study of the channel modelling in urban environments has been approached and I have tested the deterministic ray-tracing-based channel model (that is already used in the 3G and 4G case) on EXACT+IDL software. Then, in order to extend the case of study, I have considered the atmospheric attenuation by gases in a complex environment, in particular water vapour and oxygen. Furthermore, the attenuation by rain is also included in the model.
Finally, some simulations have been carried out in order to compare the results in the presence or in absence of the atmospheric attenuation. Besides, we conducted some simulations to compare the 5G vs 4G systems when we utilized a very directive antenna vs a sectorial antenna. In the first case, we tested that the

signal level to the users is higher than in the second case, but the interferences are lower because of the beamforming strategy.

To reach this aim, the following references have been mainly considered and studied:

[1] Robert E Collin, Antennas and radiowave propagation, McGraw-Hill, 1985.
[2] Theodore S Rappaport, Yunchou Xing, George R MacCartney Jr, Andreas F Molisch, Evangelos Mellios, and Jianhua Zhang, "Overview of millimetre wave communications for fifth-generation (5G) wireless networks with a focus on propagation models," arXiv preprint arXiv:1708.02557, 2017.
[3] Tan Kim Geok, F Hossain, MN Kamaruddin, Noor Ziela Abd Rahman, Sharlene Thiagarajah, Alan Tan Wee Chiat, andCP Liew, "A comprehensive review of efficient ray-tracing techniques for wireless communication", International Journal on Communications Antenna and Propagation, vol. 8, no.2, pp. 123–136, 2018.
[4] "Attenuation by atmospheric gases", Recommendation ITU-R P.676-11 (09/2016).
[5] Mansoor Shafi, Jianhua Zhang, Harsh Tataria, Andreas F Molisch, Shu Sun, Theodore S Rappaport, Fredrik Tufvesson, Shangbin Wu, and Koshiro Kitao, "Microwave vs. millimeter-wave propagation channels: Key differences and impact on 5G cellular systems, "IEEE Communications Magazine, vol. 56, no. 12, pp. 14–20, 2018.
[6] Shihao Ju and Theodore S Rappaport, "Millimeter-wave extended NYUSIM channel model for spatial consistency,"arXiv preprint arXiv:1808.07099, 2018.

[7] Jae-Hyun Lee, Jeong-Sik Choi, and Seong-Cheol Kim, "Cell coverage analysis of 28 GHz millimetre wave in urban micro-cell environment using 3-D ray tracing, "IEEE Transactions on Antennas and Propagation, vol. 66, no. 3, pp. 1479–1487,2018.

4. Products

   a. Publications:
      1. M Gargiulo, D A G Dell'Aglio, A Iodice, D Riccio, G Ruello, Integration of Sentinel-1 and Sentinel-2 Data for Land Cover Mapping Using W-Net - Sensors

      2. C Cavallo, M N Papa, M Gargiulo, G Palau-Salvador, P Vezza, G Ruello, Continuous monitoring of the flooding dynamics in the Albufera wetland (Spain) by Landsat-8 and Sentinel-2 data-sets - Wetland (on review)

      3. DAG Dell'Aglio, M Gargiulo, A Iodice, D Riccio, G Ruello, Fire Risk Analysis By Using Sentinel-2 Data: The Case Study Of The Vesuvius In Campania, Italy - IGARSS 2020

      4. M N Papa, M Nones, C Cavallo, M Gargiulo, G Ruello, Data-fusion of satellite and ground sensors for river hydro-morphodynamics monitoring - EGU 2020
      5. M N Papa, M Nones, C Cavallo, M Gargiulo, G Ruello, River hydro-morphodynamics monitoring by satellite and ground sensors data-fusion - IAHR 2020

5. Conferences and Seminars

I have taken part at the following conference/seminar:

a. International Geoscience and Remote Sensing Symposium (IGARSS) '20
b. EGU '20
c. 6th IAHR Europe Congress 2020

6. Activity abroad

I have spent two months abroad at the DLR, Oberpfanfenhoffen, Germany.

7. Tutorship

Co-tutor of a Bachelor Degree thesis student:

1. Radiocopertura per sistemi 5G: algoritmi di Ray tracing - Student: Maria Laura Vollero, Supervisor: Giuseppe Ruello.