PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Ciotola Matteo

Cycle: XXXVI

Training and Research Activities Report
Year: First

Tutor: prof. Scarpa Giuseppe

Co-Tutor:

Date: October 19, 2021

1. Information:

- **PhD student: Ciotola Matteo**
- **DR number: DR995044**
- **Date of birth: 04-18-1995**
- **Master Science degree: Automation Engineering**
- **University: Università degli Studi di Napoli Federico II**
- **Doctoral Cycle: XXXVI**
- **Scholarship type: UNINA**
- **Tutor: Prof. Scarpa Giuseppe**
- **Co-tutor:**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Modeling Complex System	Course	26	6	09/01/2020 - 01/30/2021	Mario Di Bernardo	Y
Elaborazione di Segnali Multimediali	Course	72	9	03/01/2021 - 05/31/2021	Luisa Verdoliva	Y
Elaborazione Numerica dei Segnali	Course	48	6	03/01/2021 - 05/31/2021	Giuseppe Scarpa	Y
IEEE - EURASIP 8 th Summer School on Signal Processing 2021	Doctoral School	25	3	09/06/2021 - 09/10/2021	Patrizio Campisi, Emanuele Maiorana	Y
Robot Manipulation and Control	Seminar	2.5	0.5	11/17/2020	Bruno Siciliano	Y
Antonio Picariello Lectures on Data Science, “Digital Project Management: Practices, processes, techniques, tools and scientific approach”	Seminar	1	0.2	11/18/2020	Dario Carotenuto	Y
Antonio Picariello Lectures on Data Science, “#andràtuttobene: Images, Texts, Emojis & Geo-data in a Sentiment Analysis Pipeline”	Seminar	1.5	0.3	11/25/2020	Serena Pelosi	Y

IEEE - Patent Searching best practices with IEEE Xplore"	Seminar	1	0.2	11/27/2021	Rachel Berrington	Y
Antonio Picariello Lectures on Data Science, “At the Nexus of Big Data, Machine Intelligence, and Human Cognition”	Seminar	1	0.2	12/02/2020	George S. Djorgovski	Y
Scientific Colloquia at SSM, Network Systems, Kuramoto Oscillators, and Synchronous Power Flow	Seminar	1.5	0.3	12/03/2020	Francesco Bullo	Y
Antonio Picariello Lectures on Data Science, “Exploiting Deep Learning and Probabilistic Modeling for Behavior Analytics”	Seminar	1	0.2	12/09/2020	Manco Giuseppe	Y
Antonio Picariello Lectures on Data Science, “Cybercrime and e-evidence: the criminal justice response”	Seminar	2	0.4	01/20/2021	Lucchetti Matteo	Y
Antonio Picariello Lectures on Data Science, “Machine learning: Causality lost in translation”	Seminar	1.5	0.3	02/10/2021	Edwin A. Valentijn	Y
Antonio Picariello Lectures on Data Science, “Approaches to Graph Machine Learning”	Seminar	1	0.2	02/17/2021	Miroslav Cepek	Y
Antonio Picariello Lectures on Data Science, “Visual Interaction and Communication in Data Science”	Seminar	2	0.4	03/03/2021	Marco Quartulli	Y
5G Academy, “Artificial Intelligence and 5G combined with holographic technology”	Seminar	2	0.4	04/27/2021	Pasquale Memmolo	Y

Antonio Picariello Lectures on Data Science, "Distributional Semantics Methods: How Linguistic features can improve the semantic representation"	Seminar	1.5	0.3	04/28/2021	Alessandro Maisto	Y
Optimized Graph Representations for Right-Wing Reddit Community Using Graph Neural Networks	Seminar	1	0.2	04/30/2021	Mohamed Diaoulè Diallo	Y
SSM Colloquia – Modelling the Complexity of Multiagent Activity for Human-AI Interaction using Dynamical Primitives	Seminar	1.5	0.3	05/06/2021	Michael Richardson	Y
Tecnologia e Libertà	Seminar	2.5	0.5	05/11/2021	Santolo Meo	Y
Introduction to Underwater Robotics	Seminar	2	0.4	05/18/2021	Gianluca Antonelli	Y
ITEE IGARSS 2021	Seminar	36.5	7.3	07/12/2021 - 07/16/2021	Michal Shimoni, Devis Tuia, Sindy Stercks and Andrew Skidmore	Y
Study on super-resolution techniques	Research		3	01/11/2020 – 31/12/2020		N
Preparation of the paper "Cloud Removal processing for Sentinel-2 scene with Deep Learning method, a multi-temporal and multi-source approach" (temporary title)	Research		3	01/11/2020 – 31/12/2020		N
Preparation of a conference paper, titled "A full-resolution training	Research		2	01/11/2020 – 31/12/2020		N

framework for Sentinel-2 image fusion" (temporary title) to IEEE IGARS Conference						
Study on "Generative Adversarial Networks"	Research		3	01/01/2021 – 28/02/2021		N
Study on PyTorch framework	Research		3	03/01/2021 – 04/30/2021		N
Enhancement on Super-Resolution of Sentinel-2 remote-sensing images	Research		2	03/01/2021 – 04/30/2021		N
Study on PNN network and new loss definition for Pan-Sharpening	Research		3	03/01/2021 – 04/30/2021		N
Neural Networks porting on PyTorch framework	Research		2	03/01/2021 – 04/30/2021		N
Study on Unsupervised Deep Learning methods	Research		3	07/01/2021 – 08/31/2021		N
Tutorship in Image Processing for Computer Vision course	Tutorship	37.5	1.5	03/01/2021 - 05/31/2021		N

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	**0**	**1.9**	**8**	**0**	**9.9**
Bimonth 2	**6**	**0.9**	**3**	**0**	**9.9**
Bimonth 3	**0**	**1.3**	**10**	**0.5**	**11.8**
Bimonth 4	**15**	**1.2**	**0**	**1.0**	**17.2**
Bimonth 5	**0**	**7.3**	**3**	**0**	**10.3**
Bimonth 6	**3**	**0**		**0**	**3**
Total	**24**	**12.6**	**21**	**1.5**	**62.1**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

The demand for high-resolution spectral images is growing thanks to their application in several commercial, defence and academic use: classification [1], land monitoring [2] , object recognition [3], visual image analysis, climate change [4].

Indeed, the main objective of satellite remote sensing is to provide accurate images of the Earth's surface. On the other side, due to many technological constraints, it is not possible to make satellites products with a great number of details. A way around the problem consists of combining multiple images with complementary features, thanks to data fusion techniques with which produce high-quality images. [5]

The research topics on which my studies are Pansharpening and Super-Resolution. They are strictly related tasks, because of the presence of both high-definition bands and low-definition bands to be upscaled to the same definition of the high ones. Many commercial satellites provide simultaneously a couple of a panchromatic band (PAN), with a high spatial and low spectral definitions, and some multispectral bands (MS), characterized by a low spatial and high spectral definitions. In these instruments, most of the spectral frequencies of MS are included in the range of frequencies of the PAN. Differently, some other satellites such as ESA Sentinel-2 ones, provide different multispectral images at different resolutions; these bands do not overlap spectrally.

To bring all the low-definition MS at the same resolution of the high-definition bands, several techniques have been already proposed. For the pansharpening problem, they could be divided into four main categories:

1. Component Substitution (CS): the multispectral image is transformed in a suitable domain and one of its components is replaced by the spatially rich PAN before transforming the MS back to its original domain [6], [7], [8];

2. Multiresolution Analysis (MRA): these methods extract the high-frequency spatial details through a multiresolution decomposition, such as wavelet transforms, Laplacian pyramids, and so on. The extracted details are then properly injected into the resized MS component [9], [10], [11];

3. Variational Optimization (VO): an analysis on the relation between MS and PAN is made to estimate a degradation filter or a sparse representation with which upscale the MS and inject correctly the details from the PAN [12], [13];

4. Machine Learning approach (ML): these techniques are mainly based on Convolutional Neural networks. They are currently the most popular solution for pansharpening, but the lack of Ground-Truth with which feed the network during the training may create some problems (generalization capability, scale invariance) [14], [15], [16];

In order to address the issue highlighted in the fourth point of the above list and to evaluate all the strategies, a common practice is to resort to the so-called Wald's protocol [17]. It could be summarized in a resolution shift paradigm: the high-definition/low-definition images couple undergoes a down-sampling process, after which they are used as input samples to the algorithms, while the original data plays the role of the Ground-Truth. In this way, a comparison between different techniques and a supervised training for the deep-learning method can be achieved [18].

The research of this first Ph.D. year has been centred on the study of the state-of-art of the Pansharpening and Super-Resolution methods and on the metrics with which to evaluate both. In particular, a new trend in this topic has caught my attention: the shift from a deep learning supervised technique to a deep learning unsupervised method [19], [20]. Indeed, the not complete capability of Machine Learning techniques to generalize in scale and the increasing definition of the satellite products entail the not complete satisfaction in the full-resolution framework, that is the operational framework. Within this scope, some efforts have been spent to develop new techniques, trying to answer the need for high-definition multispectral images with good quality. These solutions take in account different aspect of remote sensing scenario, as:

- The spatial misalignment of the bands among them
- The spatial misalignment between MS with the PAN
- Different applicability of techniques with different remote sensing sensors
- the lack of consistent "blind" metrics with which evaluate the techniques. Especially this last point is now an important part of my research field, because of a definition of new metrics, especially for the evaluation of the spatial quality of the fused product.

In the future, the developed techniques may play an interesting role in the remote sensing scenario, especially in those contexts where a correct alignment between pansharpened multispectral bands is needed. In this case, a technique designed/trained on full-resolution data could provide outcomes with a higher detail preservation jointly with a high spectral fidelity.

In summary, my current contribution counts three main outcomes: (i) a new technique for the super resolution [C1], (ii) a new CNN-based framework for pansharpening which leverage on a full-resolution learning paradigm [J1], and (iii) the introduction of a new full-resolution evaluation framework for Pansharpening [P1].

References

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4. Research products:

- **Journal Papers:**
  - **J1.** M. Ciotola, S. Vitale, A. Mazza, G. Poggi, G. Scarpa – "*Pansharpening by convolutional neural network in the full resolution framework*" – IEEE Transaction on Geoscience and Remote Sensing (**In review – "Major Review" received**)
- **Conference proceeding:**
  - **C1.** M. Ciotola, M. Ragosta, G. Poggi, G. Scarpa – "*A full-resolution training framework for Sentinel-2 image fusion*" – IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2021, pp.1260-1263 (**To appear** in Scopus)
- **Preprint:**
  - **P1.** G. Scarpa, M. Ciotola – "Full-resolution quality assessment for pansharpening" -- arXiv:2108.06144, 2021

5. Conferences and seminars attended

- **IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2021**
  - Dates: 07/12/2021 – 07/16/2021
  - Location: Web hosted
  - Co-author and presenter of the paper "*A full-resolution training framework for Sentinel-2 image fusion*"

6. Activity abroad:

None

7. Tutorship

- Tutorship for M.Sc. theses: Mario Ragosta and Antonio Martinelli
- Teaching assistance and tutorials for the course of Image Processing for Computer Vision, Prof. G. Scarpa