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

Academic year: 2021-22 - PhD Year: Second

Tutor: prof. Giuseppe Scarpa

Co-Tutor:

Date: October 31, 2022

1. Information:

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

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Scientific Programming and Visualization with Python	Courses	6	2	03/02/2022 - 03/03/2022	Prof. Alessio Botta	Y
Introduction to Deep Learning	Courses	24	6	03/14/202 - 04/27/2022	Prof. Giovanni Poggi, Eng. Diego Gragnaniello	Y
DeepLearn 2022 Summer - 6th Internation Gran Canaria School on Deep Learning	Doctoral School	36	5	07/25/2022 – 07/29/2022	Prof. Marisol Izquierdo, Prof. Carlos Martìn-Vide	Y
Intelligenza Artificiale e sistemi d'arma autonomi	Seminar	2	0.4	01/19/2022	Prof. Fosca Giannotti, Prof. Guglielmo Tamburrini	Y
The learning landscape in deep neural networks and its exploitation by learning algorithms	Seminar	1	0.2	01/21/2022	Prof. Riccardo Zecchina	Y
RAILS Mid-terms Workshop	Seminar	5	1.0	02/25/2022	Ronghui Liu, Gorazd	Y

					Marinic, et al.	
Antonio Picariello's Lectures on Data Science, "Towards a political philosophy of AI"	Seminar	2	0.4	04/11/2022	Dr. Mark Coekelbergh	
Using delays control	Seminar	2	0.4	04/21/2022 and 04/28/2022	Emilia Fridman	Y
ITEE IGARSS 2022	Seminar	15.5	3.1	7/18/2022 - 7/21/2022	Hean Teik Chuah, Xiaofeng Yang et al.	Y
Study on deep learning	Research		2	11/01/2021 - 12/31/2021		N
Study on pansharpening methods	Research		2	11/01/2021 - 12/31/2021		N
Study on Generative Adversarial Networks	Research		3	11/01/2021 - 12/31/2021		N
Preparation of the conference paper "An Adversarial Training Framework for Sentinel-2 Image Super-Resolution"	Research		3	11/01/2021 - 12/31/2021		N
Revision of a paper for "Journal of Selected Topics in Applied Earth Observations and Remote Sensing" journal	Research		2	01/01/2022 - 02/28/2022		N
Revision of two conference papers for IGARSS 2022 conference	Research		2	01/01/2022 - 02/28/2022		N
Finalization of the preparation of the paper "An Adversarial Training Framework for Sentinel-2 Image	Research		1	01/01/2022 - 02/28/2022		N

Super-Resolution" to IGARSS Conference						
Preparation of the Conference Paper "Boosted Full-Resolution Target-Adaptive Pansharpening Network" to ICIP Conference	**Research**		**2.0**	**01/01/2022 - 02/28/2022**		**N**
Preparation of the paper "Full-resolution quality assessment for pansharpening"	**Research**		**2.0**	**01/01/2022 - 02/28/2022**		**N**
Minor Review of the paper "Pansharpening by convolutional neural networks trained at full-resolution without reference"	**Research**		**1.0**	**01/01/2022 - 02/28/2022**		**N**
Experiments on unsupervised CNN for Super-Resolution of Sentinel-2 imagery	**Research**		**1.0**	**01/01/2022 - 02/28/2022**		**N**
Experiments on new loss function for pansharpening based on deep-learning	**Research**		**3.0**	**01/01/2022 - 02/28/2022**		**N**
Study on TensorFlow, Keras and PyTorch frameworks	**Research**		**1.0**	**03/01/2022 - 04/30/2022**		**N**
Study on the historical background of Deep-Learning and its new perspectives	**Research**		**0.2**	**03/01/2022 - 04/30/2022**		**N**
Preparation of a new paper for remote sensing imagery super-resolution (still no title chosen)	**Research**		**1.0**	**03/01/2022 - 04/30/2022**		**N**
Preparation of a new paper for remote	**Research**		**1.0**	**03/01/2022 -**		**N**

sensing imagery pansharpening (still no title chosen)				**04/30/2022**		
Major Review of the paper "Full-resolution quality assessment for pansharpening"	**Research**		**3.0**	**03/01/2022 - 04/30/2022**		**N**
Minor Review of the paper "Full-resolution quality assessment for pansharpening"	**Research**		**2.0**	**03/01/2022 - 04/30/2022**		**N**
Minor Review of the paper "Pansharpening by Convolutional Neural Networks in the Full Resolution Framework	**Research**		**1.0**	**03/01/2022 - 04/30/2022**		**N**
Preparation of a transaction paper (still no title chosen) for pansharpening unsupervised methods	**Research**		**6.0**	**05/01/2022 - 06/30/2022**		**N**
Study on super-resolution of remote sensing imagery	**Research**		**1.0**	**05/01/2022 - 06/30/2022**		**N**
Study on Pytorch	**Research**		**0.5**	**05/01/2022 - 06/30/2022**		**N**
Study on unsupervised methods for super-resolution	**Research**		**2.0**	**05/01/2022 - 06/30/2022**		**N**
Study on Transformers and self attention mechanisms	**Research**		**0.5**	**05/01/2022 - 06/30/2022**		**N**
Presentation of the paper "AN ADVERSARIAL TRAINING FRAMEWORK FOR SENTINEL-2	**Research**		**1.0**	**07/21/2022**		**N**

IMAGE SUPER-RESOLUTION" at IGARSS Symposium						
Chair of "Super-Resolution" Multimedia Session at IGARSS Symposium	**Research**		**1.0**	**07/21/2022**		**N**
Speech preparation for Lecture about Deep Learning and data preprocessing for IADF School – Computer Vision for Earth Observation	**Research**		**3.0**	**09/01/2022 - 10/30/2022**		**N**
Exercises preparation for Lecture about Deep Learning and data preprocessing for IADF School – Computer Vision for Earth Observation	**Research**		**2.0**	**09/01/2022 - 10/30/2022**		**N**
Lecture at IADF School – Computer Vision for Earth Observation	**Research**		**1.0**	**09/01/2022 - 10/30/2022**		**N**
Writing of "An Unsupervised Channel Spatial Attention method for Pansharpening" paper (temporary title)	**Research**		**2.0**	**09/01/2022 - 10/30/2022**		**N**
Writing of "Unsupervised Sentinel-2 fusion network" paper (temporary title)	**Research**		**0.8**	**09/01/2022 - 10/30/2022**		**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	**0.0**	**0.0**	**10.0**	**0.0**	**10.0**
Bimonth 2	**0.0**	**1.6**	**15.0**	**0.0**	**16.6**

Bimonth 3	**0.0**	**0.8**	**9.2**	**1.0**	**11.0**
Bimonth 4	**0.0**	**0.0**	**10.0**	**0.6**	**10.6**
Bimonth 5	**5.0**	**3.1**	**2.0**	**0.0**	**10.1**
Bimonth 6	**8.0**	**0.0**	**8.8**	**0.0**	**16.8**
Total	**13.0**	**5.5**	**55**	**1.6**	**75.1**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

The main objective of satellite remote sensing is to provide accurate reproductions of the Earth's surface. This can be obtained by improving hardware to resolve many more details in both space and frequency domains. However, it turns out to be a hard task because of the stringent constraint of the signal-to-noise ratio of satellite products. The usage of remote sensing imagery is increasing in these years in so many applications, such as automotive [1] [2], building, flood mapping, project planning [3], emergency management, defence, object detection [4], climate change [5], land monitoring [6]. A lot of algorithms and systems are increasingly based on remote sensing imagery, also thanks to the advent of Machine Learning techniques that automatize the control and the extraction of punctual information.
The physical and technological constraints, like the velocity of revolution of satellites, the acquisition time of the sensor, weather, and the resolution, both spatial and spectral, of sensors, still affects the outcomes and nullify part of the advantages of these techniques [7]. A way around the problem consists of combining multiple images with complementary features, acquired by both the same and different sensors, to get high-quality products through signal processing [8]. Data fusion is becoming a key asset in remote sensing, enabling cross-sensor [9] [10], cross-resolution [11] or cross-temporal [12] analysis and information extraction.
In more detail, many Earth observation systems, such as GeoEye, Pleiades, or WorldView, acquire a single full-resolution panchromatic band (PAN), responsible for the preservation of geometric information, along with a multispectral (MS) image at the lower spatial resolution, with rich spectral information. In these instruments, most of the spectral frequencies acquired by MS are completely or partially covered also by the sensor which acquires the PAN. For this reason, it is possible to state the Pansharpening problem as a data fusion technique, since one would aim at combining the spatial details resolved by the PAN (but not present in the MS) and the several spectral bands of the MS image (against the single band of the PAN) in a unique product [13].
Several taxonomies have been applied to pansharpening algorithms over the years, but the most used classification collects these in four main classes, characterized by well-distinguished properties:

1. Component Substitution (CS): the MS image is transformed in a suitable domain, one of its components is replaced by the spatially rich PAN, and the image is transformed back into the original domain [14] [15] [16].
2. Multi-Resolution Analysis (MRA): These methods extract high-frequency spatial details through a multiresolution decomposition, such as decimated or undecimated wavelet transforms, Laplacian pyramids, or other non-separable transforms. Extracted details are then properly injected into the resized MS component [17] [18] [19].

3. Variational Optimization (VO): rely on the solution of an optimization problem [20] [21].
4. Machine Learning (ML): these techniques are based on Convolutional Neural Networks (CNNs). This category is currently the most popular approach and can be divided into two subcategories:
    1. Supervised: the training is achieved through a resolution shift paradigm: the available data undergoes a down-sampling process, after which the downgraded version is used to feed the network, while the original data plays the role of ground truth [22] [23] [24].
    2. Unsupervised: explores hidden patterns and features without any labelled data, which means that there is no need to simulate datasets with labels for training. It is a direct way for network training but is strongly dependent on the effectiveness of the loss function [13] [25] [26].

Differently, some other satellites such as ESA Sentinel-2 ones, provide different multispectral images at different resolutions; these bands generally do not overlap spectrally. In this case, the data fusion framework can be exploited to bring the lowest resolution bands to the highest resolution possible, through the use of data acquired by the same satellite [27] or by others with higher resolution (but with different dynamic characteristics) [28].

The research studies in the second year of my PhD program are based on these assumptions. I have tried and am trying to develop an algorithm for the pre-processing of the available data, to produce data with richer information (reconstructed thanks to AI) and to generate others when they are not physically available (partially or completely). The main topics of my investigations are the spatial enhancement of optical data. In particular, I am developing an algorithm for the super-resolution on a single remote sensing image (SISR) and Pansharpening. These applications try not only to enhance the resolution of each band but also to solve intrinsic problems of available data. Data indeed suffers from problems such as misalignment of bands among them, misalignment of data taken by different sensors, and moving objects that create artefacts and shadows. Furthermore, many deep learning solutions lack generalization capability, which means the software works well on the training/own data but suffers when a new test zone is used. This aspect is critical also for the non-trivial cost of commercial data. For this reason, I am spending much effort constructing lightweight architectures and techniques able to adapt, with few epochs, to new data.

References

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4. Research products:

- Journal Papers
    1. 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* 60 (2022): 1-17 (Published, Indexed in Scopus and ISI Web of Science)
    2. G. Scarpa, M. Ciotola – "Full-resolution quality assessment for pansharpening" - *Remote Sensing* 14.8 (2022): 1808 (Published, Indexed in Scopus and ISI Web of Science)
- Conference proceeding:
    1. M Ciotola, A Martinelli, A Mazza, G Scarpa – "An Adversarial Training Framework for Sentinel-2 Image Super-Resolution" - IGARSS 2022-2022 IEEE International Geoscience and Remote Sensing Symposium, pp. 3782-3785 1808 (Published, to appear in Scopus and ISI Web of Science)

5. Conferences and seminars attended

- *IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 2022*
    - *Dates: 07/18/2022 – 07/22/2022*
    - *Location: Web hosted*
    - *Co-author and presenter of the paper "AN ADVERSARIAL TRAINING*
    - *FRAMEWORK FOR SENTINEL-2 IMAGE SUPER-RESOLUTION"*

6. Periods abroad and/or in international research institutions

7. Tutorship

Teaching assistance and tutorials for the course of Image Processing for Computer Vision, Prof. G. Scarpa

8. Plan for year three

During my third year of the PhD program, I will focus on intra- and inter-band misalignment problems. I will also try to consolidate lightweight CNNs capable of competing with the State of Art methods both of Pansharpening and Single Image Super Resolution problems. Furthermore, I will concentrate efforts on multitemporal data, trying to emphasize the links between the acquisition taken on two different dates of the same scene, exploiting the information to provide more useful data for subsequent tasks: some ideas may be the use of different dates to estimate occluded part of images or dates not available at all, or again a different task of super-resolution.

In the third year, I will collaborate with the OBELIX team, part of the IRISA research group. For this reason, I will spend 3 months at Université Bretagne Sud, at Vannes, starting from 1st November 2022 to 31st January 2023.

Surely, as the previous years, I will do some tutorship activities, helping Professor Scarpa during the “Image Processing for Computer Vision” course.

Finally, I will write my PhD thesis, which will be centred on deep learning solutions for Data Fusion tasks in the remote sensing scenario.