UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

Activities and Publications Report

PhD Student: Matteo Ciotola

Student ID: DR995044

PhD Cycle: XXXVI
PhD Cycle Chairman: Prof. Stefano Russo

PhD program student's start date: 01/11/2020
PhD program student's end date: 31/10/2023

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PhD scholarship funding entity:

Università Federico II

General information

Matteo received in year 2020 the Master Science degree in Automation Engineering from the University of Napoli Federico II. He attended a curriculum in image processing for remote sensing optical data within the PhD program in Information Technology and Electrical Engineering. He received a grant from Università Federico II.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1	Modeling Complex System	Ad hoc course	6	Prof. Mario Di Bernardo	Scuola Superiore Meridionale
1	Elaborazione Numerica dei Segnali	MSc course	6	Prof. Giuseppe Scarpa	University Federico II
1	Elaborazione di Segnali Multimediali	MSc course	9	Prof. Luisa Verdoliva	University Federico II
2	Introduction to Deep Learning	Ad hoc course	6	Prof. Giovanni Poggi, Prof. DIego Gragnaniello	External course
2	Scientific Programming and Visualization with Python	Ad hoc course	2	Prof. Alessio Botta	ITEE
3	Visione per Sistemi Robotici	MSc course	9	Prof. Davide Cozzolino	University Federico II

Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
1st	IEEE - EURASIP 8 th Summer School on Signal Processing 2021 (S3P)	Rome, Italy	3.0	06/09/2021 - 10/09/2021	Roma Tre University, IT
2nd	DeepLearn 2022 Summer	Las Palmas de Gran Canaria, Spain	5.0	25/7/2022 - 29/7/2022	Institute for Research Development, Training and Advice – IRDTA, Brussels/London

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	Robot Manipulation and Control	0.5	Prof. Bruno Siciliano	University of Naples Federico II	Prof. Paolo Dario, Scuola Superiore Sant'Anna Pisa

1	Digital Project Management: Practices, processes, techniques, tools and scientific approach	0.2	Prof. Dario Carotenuto	Project Management Institute	University Federico II
1	#andràtuttobene: Images, Texts, Emojis & Geo-data in a Sentiment Analysis Pipeline	0.3	Dr. Serena Pelosi	University of Salerno	University Federico II
1	Patent Searching best practices with IEEE Xplore	0.2			IEEE
1	At the Nexus of Big Data, Machine Intelligence, and Human Cognition	0.2	Prof. George S. Djorgovski	California Institute of Technology	University Federico II
1	Network Systems, Kuramoto Oscillators, and Synchronous Power Flow	0.3	Prof. Francesco Bullo	UC Santa Barbara	Scuola Superiore Meridionale
1	Exploiting Deep Learning and Probabilistic Modeling for Behavior Analytics	0.2	Prof. Giuseppe Manco	ICAR-CNR	University Federico II
1	Cybercrime and e-evidence: the criminal justice response	0.4	Eng.Matteo Lucchetti	C-PROC	University Federico II
1	Machine learning: Causality lost in translation	0.3	Prof. Edwin A. Valentijn	University of Groningen	University Federico II
1	Approaches to Graph Machine Learning	0.2	Eng. Miroslav Cepek	Oracle Labs	University Federico II
1	Visual Interaction and Communication in Data Science	0.4	Eng. Marco Quartulli	Vicomtech	University Federico II
1	Artificial Intelligence and 5G combined with holographic technology	0.4	Dr. Pietro Ferraro, Dr. Pasquale Mammolo	Telco	University Federico II
1	Distributional Semantics Methods: How Linguistic features can improve the semantic representation	0.3	Prof. Alessandro Maisto	University of Salerno	University Federico II
1	Optimized Graph	0.2	Eng. Mohamed	University of Bielefeld	University Federico

	Representations for Right-Wing Reddit Community Using Graph Neural Networks		Diaoulè Diallo		II
1	Modelling the Complexity of Multiagent Activity for Human-AI Interaction using Dynamical Primitives	0.3	Prof. Michael Richardson	Macquarie University	Scuola Superiore Meridionale
1	Tecnologia e Libertà	0.5	Prof. Gaetano Manfredi, Prof. Edoardo Massimilla	University Federico II	University Federico II
1	Introduction to Underwater Robotics	0.4	Prof. Gianluca Antonelli	University of Cassino	University Federico II
1	IEEE IGARSS 2021	7.3	Michal Shimoni, Devis Tuia, Sindy Stercks and Andrew Skidmore	Geoscience and Remote Sensing Society	IEEE
2nd	Intelligenza Artificiale e sistemi d'arma autonomi	0.4	Prof Fosca Giannotti, Prof. Guglielmo Tamburrini	University Federico II	University Federico II
2	The learning landscape in deep neural networks and its exploitation by learning algorithms	0.2	Prof. Riccardo Zecchina	Bocconi University	University Federico II
2	RAILS Mid-terms Workshop	1.0	Ronghui Liu, Gorazd Marinic, Lorenzo De Donato,	University Federico II	University Federico II
2	Towards a political philosophy of AI	0.4	Mark Coekelbergh	University of Wien	University Federico II
2	Using delays control	0.4	Prof. Emilia Fridman	Tel Aviv University	University Federico II
2	IEEE IGARSS 2022	3.1	Hean Teik Chuah, Xiaofeng Yang, Tuong-Thuy Vu and Hong Tat Ewe	Geoscience and Remote Sensing Society	IEEE
3rd	IEEE IGARSS 2023	3.1	Dino Ienco, Charlotte Pelletier, Paolo Gamba,	Geoscience and Remote Sensing Society	IEEE

		Francescopaolo Sica, Paul Aimé, Sveinn E. Armannsson, Alejandro C. Frery		

Research activities

Matteo Ciotola's research has been mainly focused on remote sensing optical image enhancement. His research can be divided in five activities:

First activity: The first activity involves the fusion of multispectral data (characterized by low spatial and high spectral resolution) with panchromatic data (having high spatial but low spectral resolution) to create an image with both high spatial and spectral resolution. This research led to the development of a novel assessment procedure, which includes a reprojection method for assessing spectral consistency, a new structural index, and an innovative full-resolution training framework for deep learning algorithms. Initially, this training procedure was tested on state-of-the-art convolutional neural networks, demonstrating its effectiveness. Subsequently, it was further enhanced in terms of computational efficiency and accuracy by introducing a coregistration-at-loss scheme to address misalignment between multispectral and panchromatic data, a new spectral loss function, and a CNN architecture built upon recent advancements in computer vision. The outcomes achieved with this framework ensure high-quality both in terms of spectral and spatial aspects for the fused product.

Second activity: The second activity centres on the multi-resolution fusion of data from remote sensing satellites, particularly ESA Sentinel-2 satellites. These satellites offer bands with varying resolutions that do not spectrally overlap. The objective is to utilize the highest-resolution bands to enhance the resolution of the others. The research focuses on the development of an unsupervised convolutional neural network capable of upscaling both 20m and 60m bands to 10m resolution.

Third activity: Some satellites, like PRISMA, provide tens or hundreds of bands instead of the typical four to eight found in multispectral sensors. Not all these bands have spectral overlap wi the panchromatic image. Consequently, hyperspectral pansharpening poses distinct challenges compared to multispectral data. The research aims to adapt an unsupervised convolutional neural network designed for multispectral images to address hyperspectral data. The proposed contribution takes into consideration various factors, such as band variability, computational demands, and the limited availability of training data, while delivering promising results within a reasonable timeframe.

Fourth activity: Optical sensors capture sunlight reflected by the Sun, limiting their operation to daytime and making them sensitive to weather conditions. In contrast, Synthetic Aperture Radar (SAR) sensors are active and can acquire data under any conditions. One potential solution is to

use SAR data to reconstruct missing or corrupted information in optical data. Although preliminary, the results are promising.

Fifth activity: The fifth activity explores the concept of multiple image super-resolution for remote sensing data as a solution to address signal-to-noise ratio constraints. The fixed orbits of satellites enable the acquisition of multiple images of the same area in a limited time frame. During the research conducted at the University of Bretagne Sud, preliminary studies were carried out to investigate this problem.

Tutoring and supplementary teaching activities

Matteo Ciotola tutored 3 MSc students of Computer Engineering, held some tutorial lessons for Image Processing and Computer Vision course and helped, as volunteer, for "Porte Aperte" event, organized by University Federico II

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	24	12.6	21	1.5
2nd	13	5.5	55	1.6
3rd	9	3.1	60	1.8

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
3rd	Université Bretagne Sud	Prof. Charlotte Pelletier	1/11/2022-31/01/2023	Research on multiple images super resolution (MISR) for remote sensing imagery

PhD Thesis

Satellite remote sensing provides detailed, large-scale Earth images.

Many applications rely on this information, and there is a strong demand for more and better data. No single sensor provides all the information of interest, which motivates the growing appeal of data fusion.

Due to the limitations of the sensors, the acquired images cannot have simultaneously high spatial and spectral resolution. To overcome this problem, two coupled sensors can be used, acquiring a high-resolution panchromatic image and a low-resolution multispectral image. The fusion technique known as *pansharpening* aims to fuse them to obtain an ideal high-resolution multispectral image. Many model-based pansharpening methods have been developed in recent decades. Recently, research has shifted towards data-driven solutions, hoping to replicate the successes observed in other application fields. The results, however, did not meet these high expectations. This is likely due to the lack of full-resolution real-world data, which prevents the use of supervised learning. To around this limitation, many models are trained on low-resolution synthetic data and then used on the high-resolution data of interest. This approach, however, is based on a dubious assumption of scale invariance and provides questionable results.

This thesis proposes a new training framework that works on original high-resolution images, avoiding downscaling and consequent impairments. The framework encompasses novel methods to evaluate the spectral and spatial fidelity of the pansharpened image compared to the original multispectral and panchromatic data. Experiments on real data demonstrate that the proposed methods outperform the current state of the art. Further contributions include on-the-fly band co-registration and weights adaptation, and new perception-based distortion indexes.

Publications

Research results appear in 5 papers published in international journals (and 1 under review – major), and 5 contributions to international conferences.

List of scientific publications

International journal papers

M. Ciotola, S. Vitale, A. Mazza, G. Poggi and G. Scarpa,
Pansharpening by Convolutional Neural Networks in the Full Resolution Framework,
IEEE Transactions on Geoscience and Remote Sensing,
vol. 60, pp. 1-17, 2022, Art no. 5408717, doi: 10.1109/TGRS.2022.3163887.

G. Scarpa and M. Ciotola,
Full-Resolution Quality Assessment for Pansharpening,
Remote Sensing,
vol. 14, no. 8, p. 1808, Apr. 2022, doi: 10.3390/rs14081808.

M. Ciotola and G. Scarpa,
Fast Full-Resolution Target-Adaptive CNN-Based Pansharpening Framework,
 Remote Sensing,

vol. 15, no. 2, p. 319, Jan. 2023, doi: 10.3390/rs15020319.

M. Ciotola, G. Poggi and G. Scarpa,

Unsupervised Deep Learning-Based Pansharpening With Jointly Enhanced Spectral and Spatial Fidelity,

IEEE Transactions on Geoscience and Remote Sensing,

vol. 61, pp. 1-17, 2023, Art no. 5405417, doi: 10.1109/TGRS.2023.3299356.

G. Guarino, M. Ciotola, G. Vivone, G. Poggi, G. Scarpa,

PCA-CNN Hybrid Approach for Hyperspectral Pansharpening,

IEEE Geoscience and Remote Sensing Letters, doi: 10.1109/LGRS.2023.3326204

G.Guarino, M. Ciotola, G. Vivone, G. Scarpa,

Band-wise Hyperspectral Image Pansharpening using CNN Model Propagation,

IEEE Transactions on Geoscience and Remote Sensing, (**Under Review**)

International conference papers

M. Ciotola, M. Ragosta, G. Poggi and G. Scarpa,

A Full-Resolution Training Framework for Sentinel-2 Image Fusion,

2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS,

Brussels, Belgium, 2021, pp. 1260-1263, doi: 10.1109/IGARSS47720.2021.9553199.

M. Ciotola, A. Martinelli, A. Mazza and G. Scarpa,

An Adversarial Training Framework for Sentinel-2 Image Super-Resolution

2022 IEEE International Geoscience and Remote Sensing Symposium, IGARSS,

Kuala Lumpur, Malaysia, 2022, pp. 3782-3785, doi: 10.1109/IGARSS46834.2022.9883144.

M. Ciotola, G. Guarino, A. Mazza, G. Poggi, G. Scarpa

Pansharpening by efficient and fast unsupervised target-adaptive CNN

2023 IEEE International Geoscience and Remote Sensing Symposium, IGARSS,

Pasadena (CA), United States of America, 2023 pp. 5579-5582

A. Mazza, M. Ciotola, G. Poggi, G. Scarpa

Synergic use of SAR and optical data for feature extraction

2023 IEEE International Geoscience and Remote Sensing Symposium, IGARSS

Pasadena (CA), United States of America, 2023 pp. 2061-2064

G. Guarino, M. Ciotola, G. Poggi, G. Vivone, G. Scarpa

An unsupervised CNN-based hyperspectral pansharpening method

2023 IEEE International Geoscience and Remote Sensing Symposium, IGARSS

Pasadena (CA), United States of America, 2023 pp. 5982-5985

Awards and Prizes

- Prof. Francesco Carassa Award, given by Gruppo Telecomunicazioni e Tecnologie dell'Informazione (GTTI) and Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT), by presenting the poster "CNN-based Unsupervised Pansharpening" - Authors: M. Ciotola, G. Poggi, G. Scarpa

Date ___31/10/2023_____   **PhD student signature** _____

Supervisor signature _____