PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Alessio Di Simone

XXIX Cycle

Training and Research Activities Report – First Year

Tutor: Daniele Riccio

1. Information

Alessio Di Simone, MSc in Telecommunications Engineering – Università di Napoli Federico II.

XXIX Cycle - ITEE – Università di Napoli Federico II.

Tutor: Daniele Riccio

My fellowship – named "Sistemi di telecomunicazione innovativi a larga banda anche con impiego di satelliti per utenze differenziate in materia di sicurezza, prevenzione e intervento in caso di catastrofi naturali" – is funded by the MIUR within the FSG program.

2. Study and Training activities
   a. Courses
      - Ad hoc Course, *"Theory and Applications of Piecewise Smooth Dynamical Systems"* from June 16th to June 20th 2014.
      - Ad hoc Course, *"Introduzione alla Meccanica Quantistica"*, from May 2014 to July 2014.
      - Ad hoc Course, *"Corso di Europrogettazione",* from October 2014 to November 2014.
      - Ad hoc Course, *"Aspetti elettromagnetici nella progettazione di reti wireless",* from January 2015 to February 2015.
      - Ad hoc Course, *"Elettromagnetismo e Relatività",* February 2015. (to be completed).
      - Ad hoc Course, *"Project Management",* February 2015. (to be completed).
   b. Seminars
      - *"A Few Principles of Estimation Theory",* by Prof. Richard Bamler, from March 10th to March 12th, University of Napoli Parthenope.
      - *"Patch based models for image processing and patch based model for SAR imagery",* by Prof. Florence Tupin, from March 10th to March 12th, University of Napoli Parthenope.
      - *"Sequence Design for Performance Improvement in Active Sensing Systems",* by Dr. Mohammad Mahdi Naghsh, May 15th 2014
      - *"High-Dimensional Pattern Recognition",* by Dr. Allen Yang, June 6th 2014.
      - *"10 years of Medical Microwave Imaging at Bristol",* by Dr. Maciej Klemm, June 9th 2014, Istituto per il Rilevamento Elettromagnetico dell'Ambiente (IREA).
      - *"Control System Design Using Energy Properties of Physical Systems",* by Dr. Alejandro Donaire, June 23th 2014.
      - Ciclo di seminari su *"Nanocarbon based components and materials for high frequency electronics",* October 6th 2014.
      - *"Developmental Robotics: From Babies to Robots",* by Prof. Angelo Cangelosi, October 10th 2014.
      - *"Quantum Teleportation",* by Prof. Miano, October 23th 2014.
      - *"Heterogeneities in temporal networks emerging from adaptive social interactions",* by Prof**.** Takaaki Aoki, November 14th 2014.
      - *"Methods and tools for smart device integration and simulation",* by Prof. Franco Fiummi, November 20th 2014.
      - *"Seminar on memory technologies for Android based systems",* by Simon Pietro Romano, December 5th 2014.
      - *"Smoothed Particle Machine Perception: a proposed method for sensor fusion and physical-spacial perception",* by Prof. Nick Hockings, January 14th 2015.
      - *"Mechanics of Solids: From beam theory to rapid prototyping for surgery planning",* by Prof. Ferdinando Auricchio, January 15th 2015.
      - *"Applications for software development: types, interactions and continuous integration",* by Dr. Antonio Almazàn Faura, January 16th 2015.
   c. External courses

- European School of Antenna (ESoA) Course, *"Antenna Synthesis",* from 13th to 17th October 2014, European School of Antennas.
- International Summer School on *"Data Fusion of Risk-related Remotely Sensed and Geospatial Data",* from September 15th to 19th 2014, University of Pavia.

	Credits year 1									Credits year 2		Credits year 3		
		1	2	3	4	5	6							
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	Check	Estimated	Check	Total
Modules	30	0	3	3	6	3	10	25	20-40	18	10-20	6	0-10	49
Seminars	8	1,2	0,9	0	1	1	0,9	5	5-10	8	5-10	5	0-10	18
Research	22	7	5	7	3	6	2	30	10-35	34	30-45	49	40-60	113
	60	8,2	8,9	10	10	10	12,9	60		60		60		180

3. Research activity

Information extraction from a single SAR image

Within the DIETI, my research group is mainly active in the remote sensing field, with a particular focus on Synthetic Aperture Radar (SAR) data modelling and processing. Within the group, my research interests are in information extraction from SAR images and modelling of the electromagnetic scattering from natural surfaces. In particular, my research project is focused on the development of proper retrieval algorithms for information extraction from a single SAR image. This research activity is particularly interesting especially in those scenarios characterized by very limited resources and strict requirements about radar system complexity, costs, weight. Space missions for celestial bodies' analysis and study, as well as developing countries will benefit from this research project.

Any information retrieval algorithm is essentially an inversion procedure, so significative issues about feasibility could arise. Due to the many factors influencing SAR data (in primis topography, (complex) dielectric constant, microscopic roughness), any algorithm aimed at recovering information from a single SAR image has to deal with ill-posedness issues: one equation in many unknowns, of which only one (or few) are of interest. Even if ill-posedness cannot be removed, thus being an intrinsic property of the problem, it could be circumvented only via a proper modelling of all the phenomena and mechanisms influencing the SAR image formation. The output of this modelling step is the direct (or forward) model, i.e., the model linking the SAR image to all the parameters influencing it. In order to provide an accurate direct model, in my research activity, SAR image modelization is based on the fractal geometry, the best tool for natural surfaces representation. After a deep study of the main scattering mechanisms and existing models, the direct model has been splitted in three concatenated steps [3]:

- Surface Model: the natural sensed surface is modelled as a 2-D fractional Brownian motion (fBm) stochastic process.
- Scattering Model: scattering mechanisms are properly modelled via a model suitable for fractal surfaces, namely the Small Perturbation Method (SPM). The scattering model provides a link between the backscattering coefficient and the geometrical and electromagnetic parameters of the surface.
- SAR image model: it links the intensity SAR image to the backscattering coefficient through the SAR acquisition system geometry. A simple model based on independent scattering from different resolution cells has been derived.

The forward model, obtained just concatenating the previous ones, provides the relationship between data and the surface parameters.

In order to circumvent in some way the subsequent ill-posedness (whatever the parameter(s) to be estimated), a sensitivity analysis of the direct model against the main surface parameters is conducted. As a result, it was found that topography (if present) is the most relevant contribution to SAR image formation. Very weaker dependencies were found against the remaining factors ((complex) dielectric constant, fractal parameters). This interesting (and expected) result gives a chance to circumvent ill-posedness: the topographic content (i.e., the local range and azimuth slopes of the surface) can be estimated just supposing the other parameters to be constant over all the scene. In order to simplify the inversion procedure, a linearization of the direct model against local slopes is performed: in a first-order approximation, the SAR image intensity depends only on the range slope, that can be easily estimated. Then, the range slope map can be exploited in different high-level products, as SAR despeckling, Digital Elevation Model (DEM) and local incidence angle estimation. SAR despeckling can greatly benefit from information on range slopes: hence, a non-local means despeckling with a similarity criterion based on local slopes has been easily set-up and very promising results were obtained. Finally, in order to recover the topographic content and the incidence angle map, a regularization procedure based on a Minimum Mean Squared Error (MMSE) is performed in order to estimate also the azimuth local slope. In order to compare the overall performances with other existing techniques, a deep study of the state of the art of both shape from shading and non-local means SAR despeckling has been conducted, trying to analyse the main advantages and drawbacks of each studied method.

In the next years, the introduction of the complete direct model, i.e., not linearized, in the inversion procedure, as well as the retrieving of the local incidence angle, rather than local slopes, will be an interesting research effort.

4. Products

Journals

[1] Di Martino, G., Di Simone, A., Iodice, A., Riccio, D., “Shape from Shading and SAR Images,” IEEE Trans. Geosci. and Remote Sens., (resubmitted).

Conferences

[2] Di Simone, A., Riccio, D., “A New Perspective in Shape from Shading from SAR Images”, *IEEE Graduate of the Last Decade (GOLD) Conference*, Berlin, June, 5-6, 2014.

[3] Di Martino, G., Di Simone, A., Iodice, A., Riccio, D., and Ruello, G., “On shape from Shading and SAR Images: an Overview and a New Perspective,” *International Geoscience and Remote Sensing Symposium (IGARSS),* Quebec City, July, 13-18, 2014.

[4] Di Martino, G., Di Simone, A., Iodice, A., Riccio, D., and Ruello, G., “Polarimetry and Shape from Shading,” *POLinSAR Conference,* Frascati, January, 26-30, 2015. (accepted)

[5] Di Martino, G., Di Simone, A., Iodice, A., Riccio, D., and Ruello, G., “SAR Shape from Shading in Suburban Areas,” *Joint Urban Remote Sensing Event (JURSE),* Lausanne, March, 30 – April 1, 2015. (accepted)

[6] Di Martino, G., Di Simone, A., Iodice, A., Riccio, D., and Ruello, G., “Electromagnetic Model for SAR Shape from Shading,” *RiNEm,* pp. 277-280*,* Padova, September, 15-18, 2014.

5. Conferences and Seminars

During this first year, I participated to the POLinSAR conference, on Science and Applications of SAR Polarimetry and Polarimetric Interferometry, organized by the European Space Agency, at Frascati (Rome)

on January, 26-30, 2015. Within the Polarimetry framework, I was a co-author of the paper “Polarimetry and Shape from Shading” together with Gerardo Di Martino and my Tutor, Prof. Daniele Riccio. I presented our work about polarimetric aspects in shape from shading in a joint poster session.

6. Activity abroad

I have spent no time abroad during the first year PhD course.

7. Tutorship

I have just started to assist a MSc student with her thesis on despeckling of SAR images based on non-local means approach.