PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Davod Poreh

XXX Cycle

Training and Research Activities Report – Second Year

Tutor: Prof Daniele Riccio

1. Information

Davod Poreh XXX Cycle - ITEE – Università di Napoli Federico II.

Tutor: Prof Daniele Riccio

2. Study and Training activities

a. Courses that I have taken during my last year in Napoli:

1- Radar systems (6 credits)

2- Mathematical foundation of filed computation and magnetic measurements for accelerator magnets (3 credits).

3- Using satellite radar for infrastracture health monitoring (3 credits)

4- Scientific writing (3 credits)

b. Seminars

1- CMOS smart gas sensors, temperature sensors and IR devices (**0.6 credits**)
2- Radar adaptively: Antenna based signal processing technique (**0.5 credits**)
3- GIELIS transformations in the natural sciences and technology (**0.2 credits**)

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	Credits year 1									Credits year 2										Credits year 3									
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Sum	Check	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Sum	Check	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Sum	Check	Total
Modules	20	0	0	0	9	9	3	21	20-40	10	12	0	3	0	0	0	15	10-20	0								0-10	36
Seminars	5	0	1.1	1.9	0.4	0.5	0.2	4.1	5-10	5	0.6	0.7	0.2	0	0	0	1.5	5-10	0								0-10	5.6
Research	30	10	8.9	8.1	0.6	0.5	6.8	35	10-35	40	2	9.3	7	10	10	10	48	30-45	60								40-60	83.2
	55	10	10	10	10	10	10	60		55	15	10	10	10	10	10	65		60									124.8

3-Research activity

My research activity has three lines:

- ✓ **a) Usage of satellite remote sensing on small scale movements of the railways in Campania**
- ✓ **b) Soil moisture retrieval via Polarimertric Two-Scale Model**
- ✓ **c) Simulation of the new fully polarimetric SAR images**

Here I briefly explain each activity:

a) In recent years, space-borne Differential Interferometric Synthetic Aperture Radar (DInSAR) techniques have shown their capabilities in monitoring of Earth surface displacements. Persistent Scatterer Interferometry (PSI) methodology is gradually becoming known for its capabilities of providing ground displacement monitoring with an accuracy up to the millimeter scale, especially in urbanized areas, where the Earth surface's deformation risk is much noticeable. In particular, Campania region is characterized by intense urbanization, active volcanoes, complicated fault systems, landslides, subsidence, and hydrological instability; therefore, the stability of public transportation structures is highly concerned. In my thesis, we have applied Differential Interferometric Synthetic Aperture Radar (DInSAR), and PSI techniques to a stack of 25 X-band radar images of Cosmo-SkyMed (CSK) satellites collected over an area in Campania (Italy), in order to monitor the railways' stability. The study area was already under investigation with older, low-resolution sensors like ERS1/2 and ENVISAT-ASAR before, but the number of obtained persistent scatterers (PSs) was too limited to get useful results. Here, for the first time we apply high resolution imagery of CSK to this study area, so obtaining a number of PSs sufficient to detect possible deformations on the railways. Our descending SAR data set cover temporal baseline between 2011 and 2015. In the average of more than 190 thousands of persistent scatterers for an area as big as 56 km^2, velocities and ensemble coherence are -1.8 mm/yr and 73%, respectively. We focused our study on a bridge at Triflisco (near Naples) over the Volturno river, on which 30 permanent scatterers (PSs) have been obtained. For the older sensors, this number was quite lower. In the studied time series, minimum velocity of -0.9 and maximum of 0.05 mm/yr with average of -0.3 mm/yr and standard deviation of 0.3 mm/yr have been observed, demonstrating the very stable condition on the bridge. Comparison with the local thermal data shows that the main deformation on the bridge is solely restricted to periodical deformation of the steel structure, with a small amount of deformation in rate of -0.30 mm/yr in the line of sight (LOS) direction. We have submitted a conference proposal (oral) to IEEE gold in Barcelona in December 2015. Also our paper regarding of this subject has been published at European journal of remote sensing, vol.49, pp. 417-431, 2016.

b) Soil moisture retrieval from remote sensing data is very useful for a number of applications, and even specific missions. When high-resolution soil moisture maps are needed, use of polarimetric SAR data is the obvious choice. However, soil moisture retrieval from SAR data is not an easy task, especially in presence of a vegetation cover, because radar return depends not only on the soil dielectric constant (and hence soil moisture) but also on several other parameters describing soil roughness and vegetation. Accordingly, in recent years some methods for soil moisture retrieval under vegetation cover have been developed. They rely on model-based or hybrid polarimetric

target decomposition techniques. Many of these decomposition techniques, in their original formulations, suffer from the so-called negative power problem, which is due, on one side, to poor modelling of surface scattering, so that the whole cross-polarization effect is attributed to volumetric scattering, which is thus overestimated; and, on the other side, to the poor modelling of the vegetation scattering contribution itself. The approach of (named *Polarimetric Two-Scale Two-Component Model*, PTSTCM) focuses on the former problem and tries to solve it by using a more refined surface scattering model that accounts for de- and cross-polarization due to surface roughness; the price to be paid is the need of ignoring double bounce contributions and still using a simplified vegetation scattering model. Conversely, the approach of (named *Iterative Generalized Hybrid Decomposition*, IGHD) focuses on improving the modelling of vegetation scattering, at the cost of still using a simplified, non-depolarizing ground scattering model. It turns out that PTSTCM provides the best results for moderately vegetated fields (vegetation height lower than 50 cm, or cross-polarized ratio smaller than 0.1, and negligible double-bounce component), whereas IGHD provides the best results in the other cases and shows a wider range of validity.
In my thesis, we first of all recall and analyse the results of the above mentioned two methods, and show a method to combine them by choosing pixel by pixel in an adaptive way the more suitable one, based on the values of the cross-polarized ratio (or, if known, of the vegetation height) and on the signum of the real part of the co-polarized correlation. It turns out that the combination of the two approaches covers most of the vegetation cover conditions. The only critical situation is the case of dominant surface scattering and secondary, non-negligible, dihedral component. Then, we propose a method to try to fill this gap, to be used when the co-polarized correlation coefficient is significantly smaller than unity and the cross-polarized ratio is very small, so that the decreased correlation coefficient is not justified by roughness or volumetric effects and it is most likely due to the dihedral component. In this case, we suggest that the more refined surface model of PTSTCM is firstly used to compute the volumetric component, so that the latter is not overestimated. Then, with this estimate of the volumetric component, soil moisture can be retrieved by recurring to one of the usual model-based or hybrid decompositions.
For this activity, we have participated in the conference of European Space Agency, ESA SP 740 (Proceedings of Living Planet Symposium 2016), Prague (Czech Republic), May 2016, CD-ROM.

c) In recent years, Synthetic Aperture Radar (SAR) Polarimetry has been successfully applied to soil moisture retrieval, forest monitoring, change detection and marine applications. Therefore, a polarimetric SAR raw signal simulator, based on a sound physical electromagnetic scattering model, would be certainly useful for mission planning, algorithm development and testing, and prediction of suitability of the system to different applications. An efficient simulator with many of the above cited features, called SARAS, is actually available in literature: in fact, it is a model-based raw signal simulator that, among other system characteristics, also accounts for the transmitting and receiving polarizations. However, it can only simulate one polarimetric channel at a time, with the result that data of different channels turn out to be independent. Accordingly, although the correct relations between channels' powers are obtained, the covariance (or coherence) matrix of the final images is not realistic.
In my thesis, we present an updated version of the SARAS simulator (which we named it Pol-SARAS) that is able to simultaneously produce the raw signals of the different polarimetric channels in such a way to obtain the correct covariance or coherence matrixes on the final images. In addition, we here only consider surface scattering, but, due to the modular structure of the

simulator, also other scattering mechanisms (volumetric, double bounce) can be included, if reliable models are available.
Pol-SARAS results are in good agreement with predictions of the PTSM theoretical approach, within the region of validity of the latter. Furthermore, the Pol-SARAS could be employed to produce new look up table for the PTSM methodology, to retrieve the permittivity, roughness, and soil moisture of the ground surfaces. Moreover, our simulated data are in good agreement with actual polarimetric SAR data for two different soil moisture conditions.
For this activity we have participated at the young professional IEEE conference at DLR (Germany) 20-21October 2016, and we have an under review paper for IEEE transaction. Also we participated at a conference in Parma (RiNEM 2016, September 2016), and a proposal for Pol-InSAR conference at Frascati 2017 has been submitted.

1. Products

Conferences

- ✓ ***Davod Poreh, Antonio Iodice, Daniele Riccio, Giuseppe Ruello, Railways' stabilities observed in Campania (Italy) by InSAR data. IEEE Young Professional, 4-6 December 2015, Barcelona.***
- ✓ ***G. Di Martino, A. Iodice, D. Poreh and D. Riccio, "Soil moisture retrieval from polarimetric SAR data: a short review of existing methods and a new one", European Space Agency, ESA SP 740 (Proceedings of Living Planet Symposium 2016), Prague (Czech Republic), May 2016, CD-ROM***
- ✓ ***G. Di Martino, A. Iodice, D. Poreh and D. Riccio, "Polarimetric SAR Raw Signal Simulation", Proceedings RiNEM 2016, Parma (Italy), September 2016, in print.***
- ✓ ***Davod Poreh, Di Martino, Antonio Iodice, Daniele Riccio, A fully polarimetric SAR raw signal simulator, IEEE Young Professional, 20-21October 2016 DLR Germany.***
- ✓ ***Gerardo Di Martino, Antonio Iodice, Davod Poreh, Daniele Riccio, Pol-SARAS: a fully polarimetric SAR raw signal simulator and its application to soil moisture retrieval, Pol-InSAR conference in Frascati 2017 (submitted).***

Papers

- ✓ ***D. Poreh, A. Iodice, D. Riccio, G. Ruello, "Railways' stability observed in Campania (Italy) by InSAR data", European Journal of Remote Sensing, vol.49, pp. 417-431, 2016.***
- ✓ ***D. Amitrano, V. Belfiore, F. Cecinati, G. Di Martino, A. Iodice, P.-P. Mathieu, S. Medagli, D. Poreh, D. Riccio, G. Ruello, "Urban Areas Enhancement in Multitemporal SAR RGB Images Using Adaptive Coherence Window and Texture Information", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol.9, no.8, pp. 3740-3752, 2016.***
- ✓ ***Gerardo Di Martino, Antonio Iodice, Davod Poreh, Daniele Riccio, Pol-SARAS: a fully polarimetric SAR raw signal simulator for extended scenes, Under review for IEEE transaction papers.***

Activity abroad

I have not spent any time abroad during the first year PhD course.