InSAR DSM using Sentinel 1 and spatial data creation

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Abstract

This article introduces an approach for Digital Surface Model (DSM) creation, using radar data. Furthermore, it highlights the remote sensing capability for spatial data creation. The research model is using Synthetic Aperture Radar (SAR) interferometry technique through the open source Sentinel Application Platform (SNAP) and open domain algorithm SNAPHU for phase unwrapping. The data used is Single Look Complex (SLC) IW mode Sentinel 1. City of Larisa in Central Greece has been selected as the case study to test the method. A total amount of 35 control points were collected on building rooftops using real time kinematic (RTK) GPS for validation purpose. The final results show the capacity of the method and the ability of Sentinel 1 data for DSM creation. The results suggest that interferometry can be a reliable method for building's height calculation at a macroscopic fashion.

Keywords: SAR; Interferometry; DSM; Sentinel 1; Spatial Data

1 Introduction

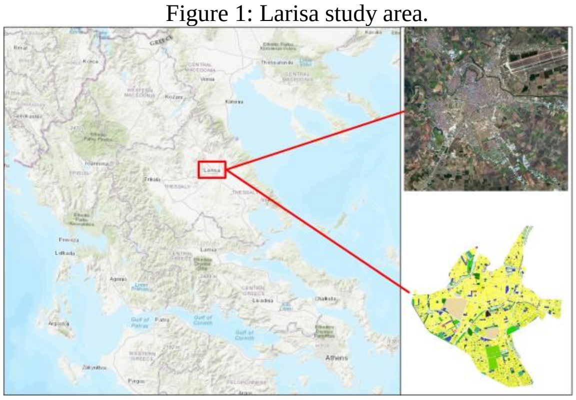
Building activity is an important part of economic and residential development. The way in which a city has been planned and expanded, has a direct impact on society's life. So urban planning aims to a rational and sustainable development of urban space and is governed by specific terms of construction. Geographical Information Systems (GIS) are an ideal solution for monitoring urban space, which is extremely complex and characterized by continuous development. Of course, the source of proper operation and exploitation of GIS system are spatial data. The main problem in Greece is lack of conventional public spatial data and especially for buildings. So researchers are called to create the necessary data from scratch. The question that arises is how spatial data can be created. To avoid excessive field work, remote sensing is an efficient method for this kind of data creation. It is worth mentioning that the Copernicus earth observation programme by the European Space Agency (ESA), offers open domain satellite data through Sentinel missions as well as open source software SNAP. This action has opened up a new dimension in earth observation science and constitutes a remarkable landmark in remote sensing history. The article is presenting an approach for building rooftops height extraction via interferometry. The data used are radar satellite images from Sentinel-1 and the processing was done using the SNAP software. Synthetic Aperture Radar (SAR) is an active, all-weather system which is based on the transmission of electromagnetic radiation. Due to the nature of SAR, it has the ability to capture the same area from slightly different angles. SAR Interferometry is a technique which has ability to highlight the phase difference between radar images and to express it in altitude values with high accuracy (Crosetto, 2002). There are many applications of interferometry and DSM extraction (Kyriou, A., Nikolakopoulos, K. 2018; Zhu, X., X., et al. 2018; Rizzoli, P., et al. 2017; Dubois, C., et al. 2016; Avtar, R., et al. 2015; Rossi, C., et al. 2013; Liao, M., et al. 2013; Zhang, W., et al. 2012; Zhou, H., et al. 2011; Wegmuller, U., et al. 2009). This type of data is crucial for urban planning, development and decision-making. Of course, interferometry is a complex technique and the result heavily depends on a lot factors, like spatial resolution of radar images, satellite wavelength, coherence, perpendicular and temporal baselines. The assumption in this article is that Sentinel-1 is not suitable for high accuracy DSM extraction because its spatial resolution in IW mode is moderate (2.7x22m to 3.5x22m – range/ azimuth). Another aspect of this article is to present remote sensing as a method for spatial data creation and to highlight the benefits of its combination with GIS systems.

2 Materials and Methods

2.1 Study area

City of Larisa in central Greece has been chosen as study area to test the method as shown in Fig. 1.

Figure 1: Larisa study area.



Source: OSM, Google Earth, Municipality of Larisa: http://gis.larissa-dimos.gr/poleodom/

Larisa is the capital of Thessaly region, the fourth most populated city and one of the most important in the whole country. Thessaly region contain the largest rural area in Greece due to the relief geomorphology and the extensive cropland.

2.2 Data

The data used is SLC IW dual-polarization (VV/VH) Sentinel-1 A/B, downloaded from the Copernicus Open Access Hub https://scihub.copernicus.eu/dhus/#/home. VV polarization was chosen for this research due to the highest sensitivity on coherence, compared with VH, between radar images. For this case study six radar images (pixel spacing-2.3x14.1m.) were collected from ascending orbit as shown in Table 1. The data were selected based on large perpendicular baseline in order to increase topography influence and on short temporal baseline for reducing atmospheric effects and temporal decomposition. Sentinel-1 is not clearly designed for DSM extraction. So, it is challenging to find image pairs with large perpendicular baseline.

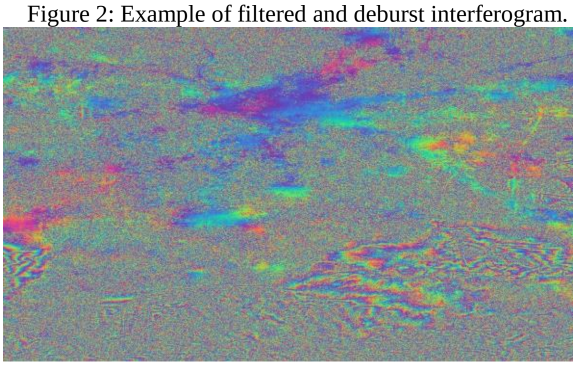
Date	Orbit	Perpendicular baseline (meters)	Temporal baseline (days)
24/05/2018	ascending	Master	-
18/05/2018	ascending	114.35	6
30/05/2018	ascending	164.13	6
18/04/2018	ascending	133.85	36
30/04/2018	ascending	158.48	24
11/07/2018	ascending	171.36	48

Table 1: Image pairs characteristics.

2.3 Method

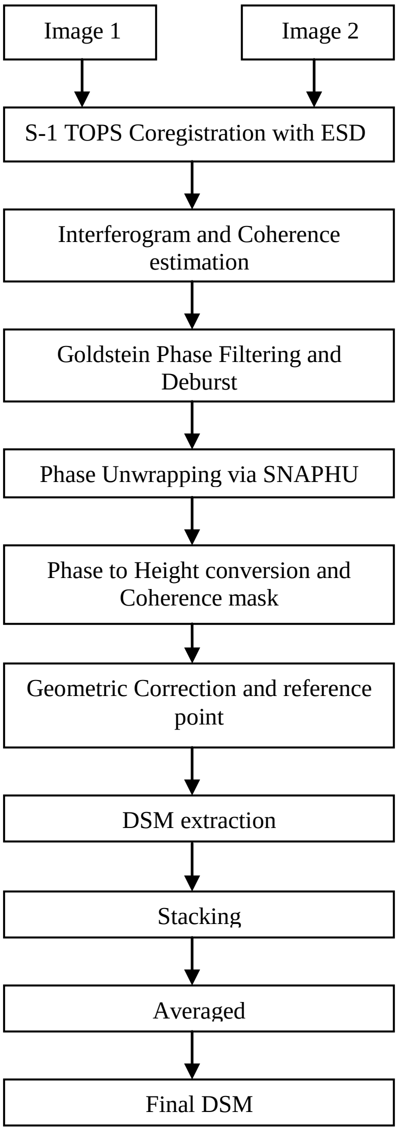
For each image pair a DSM was created and then all were averaged together. Finally, DSM was derived. Moreover, 35 altitude points were collected from building rooftops as validation means by using RTK GPS. The collection was a challenging task because most of rooftops were not accessible. Regardly, the first processing step is to split image subswath and bursts of interest. The next step was an update of orbit files. The processing continues with one of the most crucial steps, image coregistration with Enhanced Spectral Diversity (ESD). Interferogram generation is coming next, which presents the phase difference between radar images. Interferogram needs a phase filtering to reduce the residues in the later on phase unwrapping step. Filtering was performed by the Goldstein method (Goldestein, R., M., Werner, C., L. 1998) and then deburst as shown in Fig. 2.

Figure 2: Example of filtered and deburst interferogram.



Third party algorithm SNAPHU created by Chen and Zebker (https://web.stanford.edu/group/radar/softwareandlinks/sw/snaphu/) was used for unwrapping phase from modulo 2pi rad. Next, the unwrapped phase converts to height values and masked out pixels with low coherence (<0.3). Geometric correction was done in EPSG: 2100 (Greek Grid) reference system. One known altitude point from the collected GPS data was used as reference to convert all other values from radar coded system into ground values. The processing steps as shown in Fig. 3.

Figure 3: Processing flow chart using SNAP & SNAPHU.



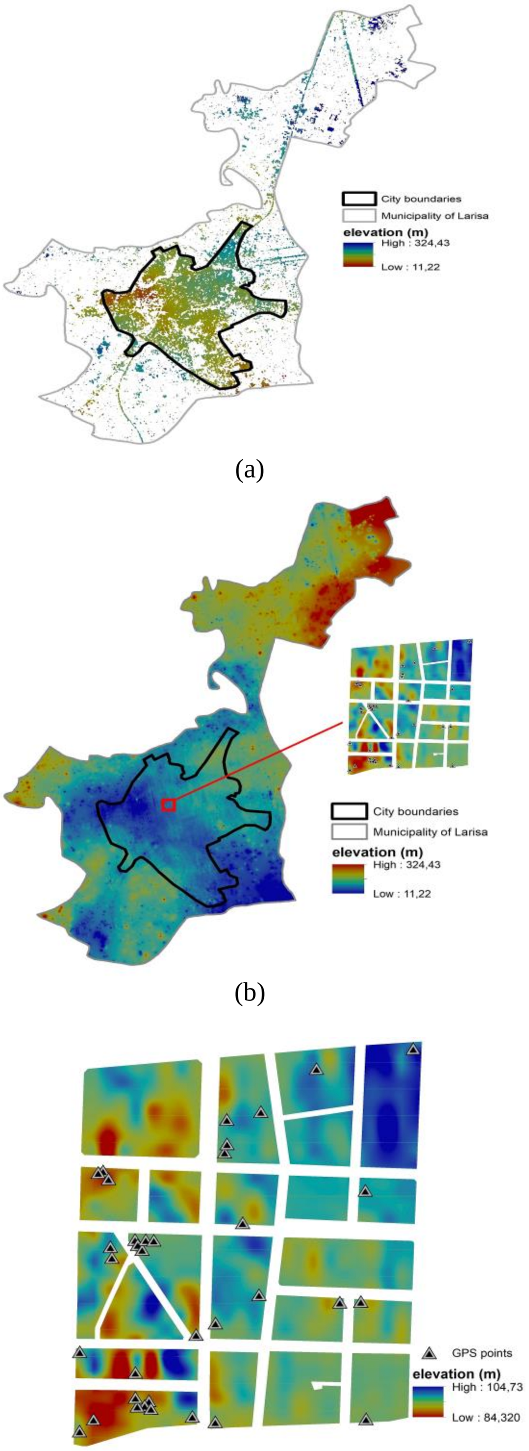
After final DSM creation, processing was continued by GIS software. An elevation void fill performed for NoData pixels due to coherence mask. Building block boundaries of city center were used, obtained by the urban planning service of Larisa.

3 Results and Validation

3.1 Results

The final results are shown in Fig. 4.

Figure 4: (a) Final DSM, (b) Final DSM after elevation void fill, (c) building blocks with GPS points.



(a)

(b)

(c)

3.2 Validation study

The validation study shows the altitude error in meters between GPS points and single corresponding pixel from derived DSM as shown in Table 2.

	x coordinate	y coordinate	GPS z (m)	DSM z (m)	Δz (m)
1	363991.99	4388307.26	97.11	95.17	1.94
2	364109.70	4388328.50	93.68	97.07	3.39
3	364087.75	4388565.79	94.41	98.40	3.99
4	364017.77	4388409.19	94.36	95.49	1.13
5	364133.81	4388442.01	95.32	97.24	1.92
6	364179.20	4388586.02	97.68	100.46	2.78
7	363929.12	4388228.26	93.16	90.92	2.24
8	364033.23	4388336.18	94.16	96.46	2.30
9	364129.67	4388329.13	94.36	95.45	1.09
10	363924.94	4388223.57	93.12	93.35	0.23
11	363931.01	4388220.51	92.96	93.59	0.63
12	363918.04	4388222.78	93.16	93.28	0.12
13	363915.91	4388392.19	95.70	95.55	0.15
14	363918.36	4388387.01	95.66	95.76	0.10
15	363922.73	4388381.98	95.74	95.76	0.02
16	363926.13	4388391.95	95.74	95.68	0.06
17	363933.76	4388391.37	95.75	95.76	0.01
18	364035.07	4388522.12	95.70	96.80	1.10
19	364002.79	4388514.14	95.75	96.73	0.98
20	364000.67	4388480.77	95.77	96.58	0.81
21	364003.06	4388489.33	95.75	96.71	0.96
22	363885.73	4388461.74	96.04	91.20	4.84
23	363881.04	4388460.22	96.05	90.96	5.09
24	363890.78	4388453.79	96.09	89.18	6.91
25	364134.68	4388210.00	95.78	95.48	0.30
26	363863.49	4388197.63	94.36	95.25	0.89
27	363876.58	4388209.68	93.21	89.58	3.63
28	363970.18	4388212.55	92.37	96.57	4.20
29	363991.88	4388206.94	94.11	94.22	0.11
30	363916.35	4388257.17	93.24	95.71	2.47
31	363863.61	4388278.19	95.17	95.25	0.08
32	363973,65	4388295.69	91.32	91.99	0.67
33	363892.60	4388384.86	95.72	97.88	2.16
34	363894.01	4388373.90	95.69	95.48	0.21
35	363916.22	4388231.76	93.09	Ref.*	-
Total mean error					**1.69**

Table 2: Total mean error in meters.

* This control point was used as reference to convert all other altitude values from radar coded system into ground values.

Typically in Greece the floor-to-floor height in buildings is approximately 3.3 meters. We can use half of this value (3.3/2=1.65m) as an acceptable level of error in the measurements with our method. This is to say that the error is acceptable when we are able to correctly count the number of stories in each building. The validation of our results indicate a mean height difference between the results and the reference values of 1.69 meters. As this value is very close to the set objective value discussed above, we believe that the results suggest that interferometry can be a reliable method for building's height calculation at a macroscopic fashion.

4 Conclusions

This article presents the capacity of interferometry for building heights extraction. Total mean error of validation study characterizes sufficient but in some cases of single pixels the error is not acceptable. Extraction of building heights is a very challenging task. The rooftops are complex. Different materials of construction are used. This affects the backscattering electromagnetic radiation in radar images. The type of this application requires very high resolution satellite data. Due to the spatial resolution, Sentinel 1 is not the ideal sensor for DSM extraction over urban areas because there is little chance to capture every single building in high accuracy. In any case, it is a useful tool for urban planning and for building heights extraction, especially in the building block scale, which will be the next case study of this research. Also, it is a valuable method for studying the changes of the built environment over time. Future work will be focused on using very high resolution radar images, larger amount of validation points and use of the Permanent Scatterer Interferometry (PSI) technique. A remarkable point is that this research was based on open domain data and open source software.

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