

OPEN-PIT MINE MONITORING USING REMOTE SENSING AND GIS

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ABSTRACT

The scope of this project is the periodic monitoring of the excavation volumes of open-pit mines, using high resolution satellite imagery stereopairs and photogrammetric methods. Two different mines located the first one at North Greece and the second one in Attiki Peninsula compose the study areas. Cartosat and ALOS Prism stereo pairs with 2.5m spatial resolution were used. The same ground control points were used for the creation of the DSMs from both CARTOSAT and ALOS PRISM stereopairs in order to eliminate horizontal and vertical discrepancies. Using LPS 3D models of the open mines were created. The head and the foot of every plane in the mine was digitized. The final step was the comparison of both 3D models' shapefiles using ArcMap 10.1® in order to calculate the excavation volumes. The excavation volumes were calculated taking into account the area of the planes and the height of every plane and the results are presented in this paper.

INTRODUCTION

A Cartosat-1 stereopair was used in order to evaluate the accuracy of ASTER and SRTM DEM (1). Although remote sensing technology has been available for many years, it has rarely been used for monitoring mining activity. Recent studies indicate that remote sensing is also a valuable tool for managing and planning certain aspects of the mining operation. On previous studies, images captured by ASTER Level 3A01 (3D Ortho Data Set), Landsat 5, and Landsat 7 satellites between 2001 and 2009 (2), and Landsat-TM and ERS-1 data sets acquired from 1989 to 1994 (3) were used to examine the areal expansion of quarries and the affect it has on vegetation. The differential interferometric synthetic aperture radar (SAR) (DInSAR) technique is used to derive the temporal land subsidence information in the Fengfeng coal mine area, Hebei province in China (5) and to depict the evolution of ground subsidence caused by repeated coal excavation (13). InSAR was used to monitor land subsidence in another mining city (12). The combination of InSAR and GPS technology is also used to monitor subsidence in coal mining areas (15, 16) In other similar studies, the researchers used a small number of GCPs derived from GPS Surveys to create stereo models from ALOS PRISM and Cartosat-1 data. (4, 6, 7, 8, 9, 10, 11, 14). ERDAS Leica Photogrammetry Suite was also used by other researchers in order to create stereo models and Orthoimages (4, 9, 10, 11).

METHODS

The study was carried for two areas in Greece, one limestone open-pit mine in Markopoulo, Attiki peninsula and one in Polygyros, Chalkidiki peninsula. Two stereo-pairs, with 2.5m spatial resolution, were acquired for each study, one from the CARTOSAT-1 satellite and one from the ALOS satellite.

Cartosat and ALOS Prism stereo pairs with 2,5m spatial resolution were used. The CARTOSAT-1 spacecraft launched by the Indian Space Research Organization in May 2005 is dedicated to

stereo viewing for large-scale mapping and terrain modeling applications. It is configured with two panchromatic cameras, AFT (Afterward looking) and FORE (Foreword looking) with a spatial resolution of 2.5 m, which facilitates along-track stereo vision of the imaging scene. It covers a swath of ≈ 30 km with a base-to-height ratio of 0.62. The time difference between the acquisitions of the same scene by two cameras is about 52 sec. The PRISM sensor onboard ALOS contains three independent optical systems (radiometers) that allow for viewing in the Nadir direction, as well as forward and backward directions. This allows for the production of a stereoscopic image along the satellite's track. Forward and backward radiometers are inclined + and $- 23.8$ degrees from nadir to realize a base-to-height ratio of one. PRISM data is collected in a single band (panchromatic) with a wavelength of 0.52 to 0.77 micrometers. The spatial resolution of PRISM is 2.5m (when viewing in the Nadir direction). Swath width of PRISM is 70km when viewing in the Nadir direction, and 35km when in triplet mode.

The objective of the project was to create 3D stereomodels –by generating DTMs and Orthoimages–, digitize each plane in the mines and then compare digitizations and calculate the excavated volumes for each mine. Using the ERDAS LPS software, GCPs were assigned to both pictures of each stereomodel. The XY coordinates of each GCP were obtained by the WMS Server of the Greek Cadastre and then the heights were exported from 5m accuracy DTMs created by the Greek Cadastre as well. The same GCPs were used for the two stereomodels of each area in order to eliminate horizontal and vertical discrepancies. The coordinate system used was the Greek Grid or EGSA 1987 which has a six-digit integral X and seven-digit Y.

Each Cartosat model consisted of one pair of scenes, whereas each ALOS model consisted of 3 pairs. For the ALOS models only one pair was used as the other two didn't depict the open pit mines. A block file was created with the ERDAS LPS for each model with the two scenes. The two scenes have an over 30% overlapped area which is the minimum for the creation of the stereomodels. About 30-40 GCPs were selected for the overlapping area and 10-20 points for the not overlapping area. The GCP cloud was denser around the mines to achieve a lower RMS Error on both horizontal and vertical axis.

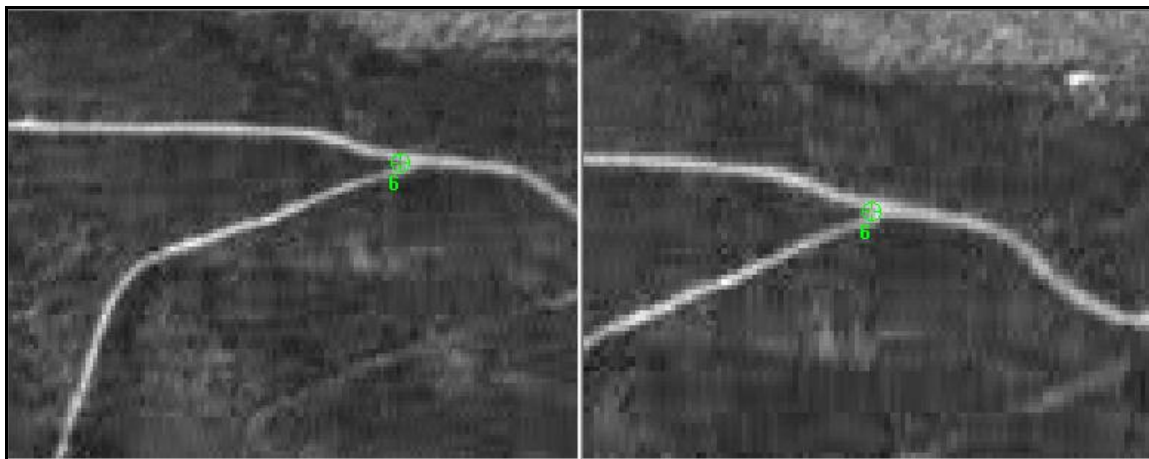


Figure 1: Example of a Ground Control Point from the ALOS stereo pair of the Markopoulo, Attiki Peninsula area.

After all the points were placed on the stereopairs, the next step was to perform Aerial Triangulation in order to calculate the RMS Error. A general rule is that the error should fluctuate in values less or equal to half the spatial resolution of the picture or half the pixel size. In this case the errors should be less than 1.25m or 0.5 pixels. After some points were excluded from the

triangulation and several corrections on the points' placement were done, the aerial triangulation error fell to under 1m or ≈ 0.4 pixels.

In order to lower the RMSE further, an ERDAS LPS feature was used, which automatically finds and places points on the scenes based on their visual similarity. It is called Automatic Tie Point Extraction. But even the fact that it is automatic, it doesn't mean that all the generated Tie Points are correct, so they all had to be checked one by one. So, the GCP cloud became denser, thus achieving better accuracy.

Continuing, after all the points were checked and was made sure that their placements and coordinates were correct, the DTMs were to be created. The DTMs were extracted using the Classic ATE method, and have 7.5m pixel size.

The next step was the Ortho Resampling and the accuracy test for each orthoimage. The orthoimages are created based on the DTMs and have, similarly to the satellite images, 2.5m pixel size. After they were created their accuracy was tested, using ArcMap, to assure that the geometric correction was performed properly. Several points with the best possible dispersion were selected, and their coordinates were compared to the coordinates from the Greek Cadastre WMS Server and it was proved that the orthoimages were very accurate inside a selected AOI which included the mines.

The final process was the digitization of the planes using ERDAS Stereo Analyst. It would be ideal to digitize the head and foot of each plane so as to assure that the plane height is the same for the two models and there is no digitization error. But for the Cartosat case it wasn't possible due to an almost vertical scene capturing of the mine area, so only the planes' head were digitized. The digitizations were saved to a shapefile which contained, amongst other attributes, the average height for each object. This attribute will help with the calculations for the excavated limestone volumes.

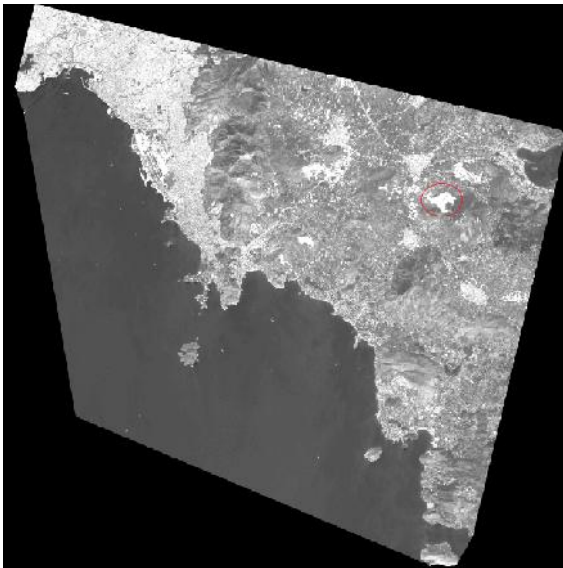


Figure 2: ALOS Orthoimage for the Markopoulo, Attiki case study. The red circle indicates the open-pit mine.

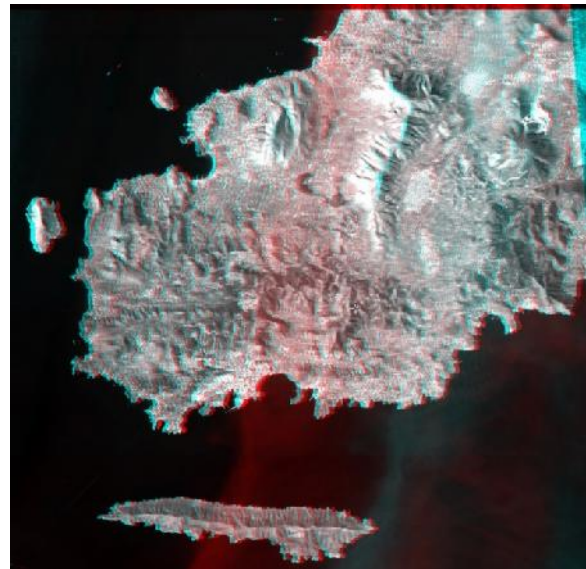


Figure 3: The Cartosat stereomodel for the Markopoulo open-pit limestone mine. The figure can be seen in 3D using Red & Green-Blue glasses.

After the two models of each case were digitized, they were loaded on ArcMap (Figure 5). Since the Cartosat imagery was captured on February 27th 2008 and the ALOS imagery on June 6th

2008, it is expected that some of the ALOS planes would subside horizontally, due to on-going excavation processes, compared to the Cartosat. The idea was to calculate the horizontal area between the Cartosat and the ALOS digitization and then multiply by the plane height to come up with the volume.



Figure 4: The ALOS stereomodel for the Markopoulo open-pit limestone mine. The black line shows the digitized head of the planes and the green shows the foot. The figure can be seen in 3D using Red & Green-Blue glasses.

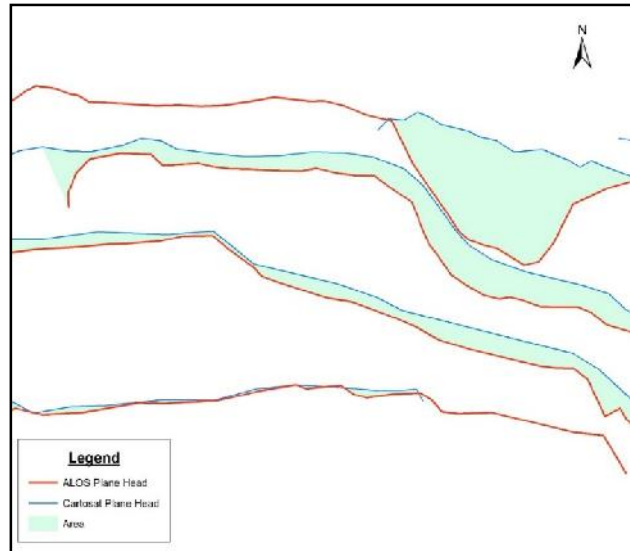


Figure 5: The comparison between the two digitizations for the Markopoulo, Attiki case study. The green polygons represent the excavated area.

CONCLUSIONS

Multitemporal and multisensor high resolution satellite stereo-data sets were used for quarry monitoring in two different locations in Greece and the calculation of the excavation volumes for an almost 4 months period in one case. The satellite stereo-data can provide a very accurate, very cheap and very quick source of data for quarry monitoring.

Synergistic use of remote sensing data, photogrammetry and GIS seems to be the most appropriate solution for quarry monitoring and excavation volumes calculation.

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