Study of Digital Elevation Model (DEM) Extraction using Stereo Radargrammetry TerraSAR-X in Madiun Area – Elevation Accuracy Improvement

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Abstract. High resolution images data from Terrasar-X are used to extract digital elevation model (DEM) using stereo radargrammetry in the attempt to achieve better resolution of terrain surface in Indonesia. As sample in this study, stereo pairs images from TerraSAR-X StripMap mode (~3m resolution) on Madiun city is used with difference of incidence angle around ~18.88 degree to extract the elevation of the area. Furthermore, field observation on the selected area will be used on elevation accuracy assessment. The digital surface elevation (DSM) generated by stereo radargrammetry in this study shows us high resolution with spatial pixel spacing 5.57 meter and elevation accuracy around ~4 meter.

1 Introduction

Synthetetic Aperature Radar (SAR) technology have been advanced through the years since its earliest day. This technology use radar as a means to observe the earth which means its not affected by clouds and time, in contrast to the optical remote sensing which affected by the clouds and only can works on day time when there's only sunlight.

On 2007, TerraSAR-X have been launched to the space carrying high frequency X band sensor, varying based on its imaging modes followed by TanDEM-X on 2010. TerraSAR-X resolution ranging around 1 m for its SpotLight mode to 40 m for Wide-ScanSAR mode. The most common mode on TerraSAR-X imagery is on its StripMap mode which have 3-meter resolution.[1]

Digital elevation model (DEM) is a digital representation of the Earth's relief that consist ordered array of elevations relative to a datum, and referenced to geographic coordinate. DEM can be distinguished by which representation on the elevation of earth surface, Digital surface model (DSM) is representing all feature on the earth surface like trees and houses while Digital Terrain model (DTM) representing the earth surface without all those features.

DEM has been a very important product on remote sensing imagery. The most used of DEM is on the process of orthorectification remote sensing image, be it as optical imagery or SAR imagery. Furthermore, its derivation can be applied on other area such as engineering works, agriculture, mining, or disaster management [2].

Stereo radargrammetry is traditional and mature approach on the elevation extraction from SAR imagery. The idea based on photogrammetry with its optical imagery while we use SAR imagery on its intensity (amplitude) to extract the elevation. As with the photogrammetry, stereo radargrammetry use two images (or more) with different incidence angles on the same area [3].

When a target is seen from different angles, the relief displacement on each SAR image will be different. The difference between the image coordinates of homologous points in a stereo pair is called parallax (leberl,1990). Each homologous point's parallax is relater to the corresponding ground target's height. When incidence angles of two sensors are constant, the target with larger parallax is higher than that with smaller parallax [4]. The optimized difference of this incident angle is ranging between 10º – 20º [5] or 15º – 25º [6].

The data we use is TerraSAR-X images which using X band on its mission. The elevation model we obtain will be a Digital Surface Model (DSM) which includes all features on earth surface as X band get backscattered at the top of any features on the earth surface.

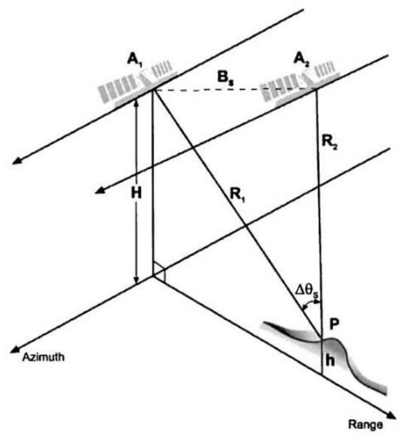

Fig. 1. Geometry of stereo-radargrammatry, A and H are the respective satellite position and altitude [7].

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Table 1. Characteristic of TerraSAR-X images pairs.

	Image 1	Image 2
Sensor	TerraSAR-X	TerraSAR-X
Imaging Mode	StripMap	StripMap
Acquisition time	24/03/2018 22.22.10-22.22.18	10/04/2018 22.13.39-22.13.48
Product Type	SSC	SSC
Scene Centere Incidence Angle	28.765	47.653
Pass	Descending	Descending
Side Look	Right	Right
Polarization	HH	HH

2 Study Area and Processing

The study is carried out around Madiun City area, East Java. The characteristic of the surface relief of this area varies around agricultural lands, urban area, hills, and mountain. This elevation from this area ranges from 60 meters to 3265 meter while the maximum altitude is the peak of Lawu mountain.

Two TerraSAR-X images have been acquired on StripMap mode with HH polarization on Single-look Slant-range Complex (SSC). These images have same-side stereo pairs on descending orbits and have difference incidence angle of ~18.88^{o} with 17 days acquisition interval.

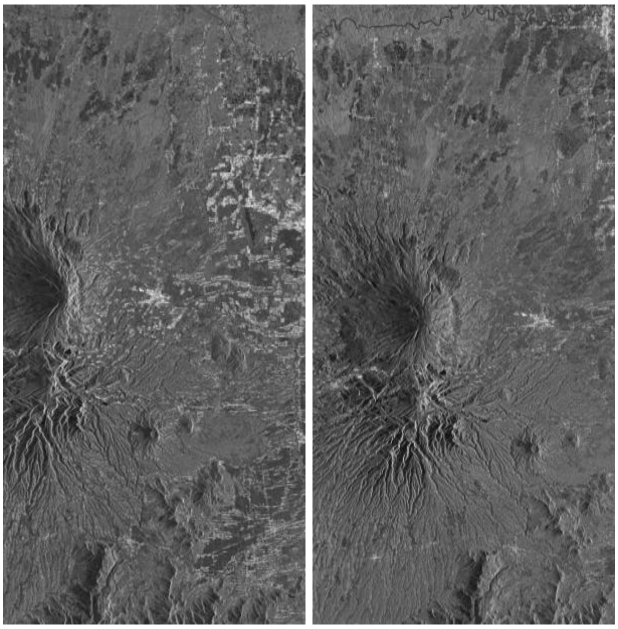


Fig. 2. Quick look of TerraSAR-X images pairs, taken at 24 March 2018 (left) and at 10 April 2018 (right).

The process of stereo radargrammetry is carried out automatically in order to achieve high precision and avoid manual interaction of the user. This is due to SAR images which are heavily distorted both radiometrically and geometrically by the terrain, such as shadow provided by slopes which facing away from the sensor. Furthermore, SAR images also contains random speckle noise which make the reduce the resolution or filter with the reference DEM to cope with this speckle noise [8].

The main idea of the stereo matching process is by retrieving a shift in pixel on range direction which is proportion.al to the topographic height. The shift then estimated by the means of co-registration between the two images using amplitude (intensity) cross correlation. This whole process is performed in pyramidal way as the estimating of initial shift is on the multi-looked ` then refining it iteration by iteration to obtain finer estimate.

Later on, these shifts are converted to height and geocoded into a map projection. The difference with basic geocoding procedure is that we applied the two antennae simultaneously in Range-Doppler equations. From there, we can obtain the height of each pixel and its location (Easting, Northing) in a given cartographic and geodetic reference system.

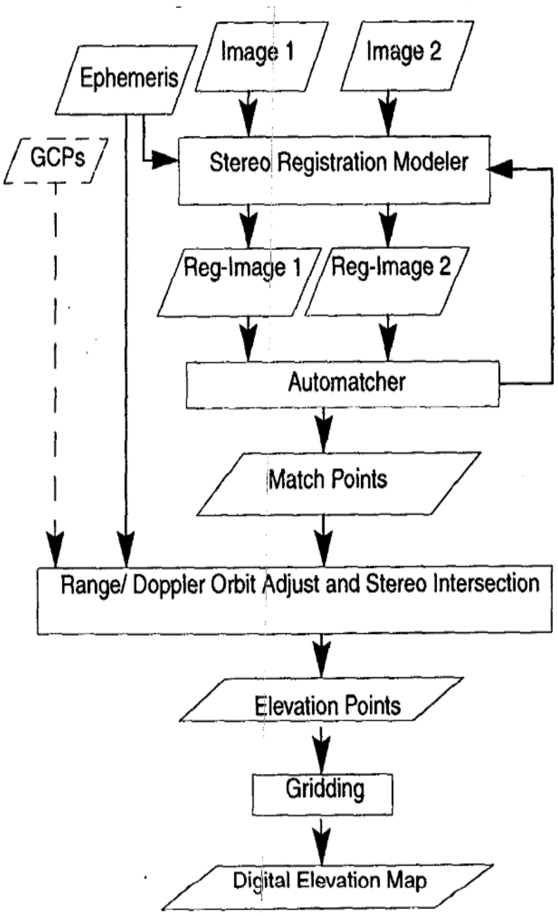
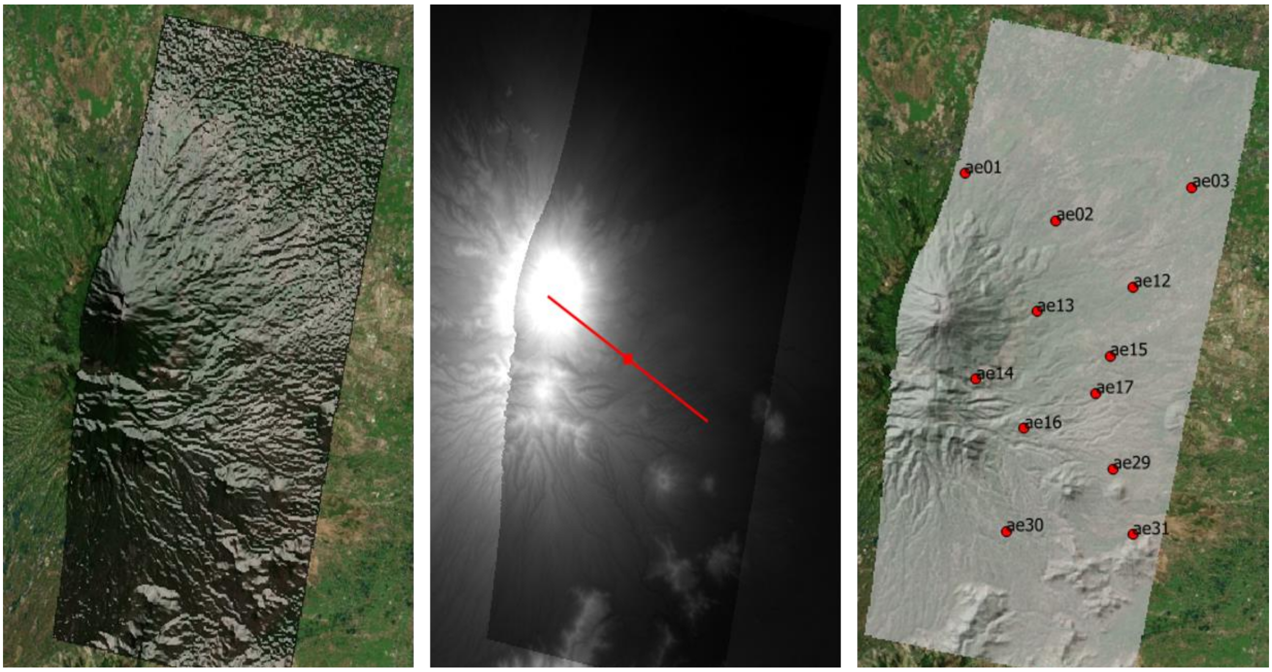


Fig. 3. Stereo radargrammetry processing flow chart [9].



a b c

Fig. 4. (a) Result of DSM stereo radargrammetry TerraSAR-X, (b) Elevation profile line of DSM stereo and DEMNAS (c) Distribution points of GPS field observation.

3 Result and Discussion

The results of Digital Surface Model (DSM) created using stereo-radargrammetry in our area of study have high resolution with spatial pixel spacing around 5.57 meter. Furthermore, we carried out elevation accuracy measurement by comparing the elevation of the stereo DSM result to field elevation observation using GNSS GPS of Garmin Geo 7X with accuracy of 0.05 meter. We also evaluate the results of stereo DSM in our study to national digital elevation model (DEMNAS Indonesia) provided by Indonesia Geospatial Agency (BIG) by taking elevation profile of these two DEM. The DEMNAS is produced from DSM of IFSAR TerraSAR-X and ALOS-PALSAR with the accuracy improvement by processing addition of mass-points, spot-heights and break-line from topographic map using GMT-surface with tension 0.32[10].

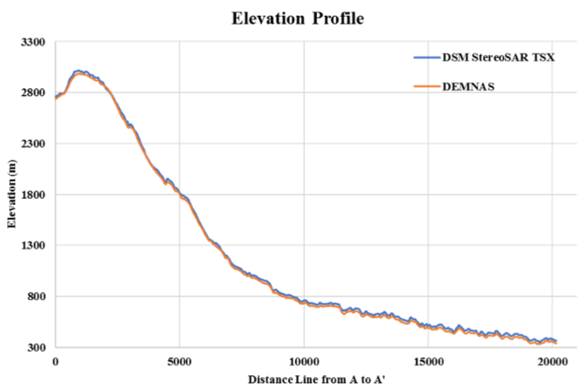


Fig. 5. Elevation profile between stereo radargrammetry DSM and DEMNAS, x-axis follow the red line on **Fig. 4**a with the elevation on the y-axis.

The elevation profile between the DSM stereo radargrammetry TerraSAR-X and DEMNAS can be seen at Fig. 5 where its elevation follows the red line on Fig. 4b. Based on both figures, the generated DSM has similar elevation profile with DEMNAS.

The elevation accuracy measurement of the DSM stereo radargrammetry TerraSAR-X using GPS field observation can be seen at Table 2 with respective points shown at Fig. 4c. The result from this measurement, we obtain the absolute mean height error of the DSM stereo radargrammetry is 3.676 meter and root mean square error is 4.018 meter with the standard deviation of error is 1.695 meter.

Table 2. Elevation accuracy measurement of stereo radargrammetry DSM with GPS field observation.

Code No.	GPS Height (m)	DSM Height (m)	Accuracy (m)
ae01	427.327	427.822	0.495
ae17	396.7880	390.772	6.016
ae02	300.5590	298.384	2.175
ae03	100.9570	105.676	4.719
ae31	249.4020	253.655	4.253
ae30	537.7290	542.123	4.394
ae29	357.1200	355.111	2.009
ae16	877.6850	879.378	1.693
ae15	388.4250	393.343	4.918
ae12	259.3960	264.910	5.514
ae13	647.8580	651.992	4.134
ae14	1321.6930	1317.897	3.796

4 Conclusion

Digital Surface Model (DSM) generation using TerraSAR-X imagery in StripMap mode at Single-look Slant-range Complex (SSC) have been generated using stereo radargrammetry. The generated DSM have spatial resolution of 5.57 meter with elevation accuracy around ~4 meter. This proves that TerraSAR-X images capable of generating digital surface model (DSM) in stereo radargrammetry and show good result from it.

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