DTM Generation from KOMPSAT-3A Stereo Images by Utilizing an Existing Low-resolution DTM

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ABSTRACT: The launch of CAS500-1/2(Compact Advanced Satellite 500) is scheduled in 2020. The generation of 3D topographic information such as Digital Surface Model (DSM) and Digital Terrain Model (DTM) using optical images derived from CAS500 is expected to be in high demand. Conventional algorithms for DTM generation try to remove non-ground points and find the ground points in DSM. It is difficult to find the correct bare-earth points in the DSM itself in case of the tree canopy and urban areas. In addition, these techniques are sensitive to the accuracy and precision of the data. Therefore, proper methods are needed for DSM acquired from optical images. We propose a method to extract non-ground points existing in DSM generated from stereo image matching by applying the low-resolution DTM that has been already built. The main concepts of DSM to DTM generation consist of non-ground point extraction, classification of building and tree canopy, and ground height estimation. Initial normalized DSM (nDSM) is created using the height difference between DSM and low-resolution DTM. As a result of performing geodesic dilation, which is offset of the initial nDSM, grid values above threshold are defined as non-ground area. Height variations are calculated along the contour of each non-ground area. The areas with a high proportion of height jump point are classified as buildings and the rest as tree canopy. In areas classified as tree canopy, the height value of DSM is decreased by offset derived from the nDSM. In contrast, in the building area, the surface value is removed, and the ground height is estimated by Inverse Distance Weighted (IDW) interpolation. In the experiment, we obtained DSMs with 2 meters of Ground Sampling Distance (GSD) from the KOMPSAT-3A stereo images by using photogrammetric image matching technique. Shuttle Radar Topography Mission (SRTM), which resolution is about 30 meters, was used as the low-resolution DTM. The target areas were selected with four challenging locations that reflect various terrain characteristics. The proposed method is evaluated against a reference DTM, which is manual data provided by National Geographic Information Institute (NGII) of South Korea. Our method flexibly extracts non-ground points that exist in various regions and generates improved results compared to the SRTM.

1. INTRODUCTION

With the increasing prevalence of high-resolution optical satellite images, it is easier to obtain high quality 3D information than before. CAS500-1/2 that is scheduled to be launched in 2020 will also provide high-resolution panchromatic images with 0.5 meters resolution. These land observation satellites are designed to take images of the same area with a time difference of 50 minutes and are expected to generate accurate and precise 3D terrain data from the stereo images captured under these conditions. From point clouds extracted through image matching technique (Rhee et al., 2018), DSMs containing the height of artificial objects and terrain or DTMs representing only ground height can be generated. These 3D topographic information are fundamental data used in a wide range of application fields such as object extraction and change detection.

In general, DSM to DTM conversion requires the extraction of non-ground area, such as artifact objects or trees, that exist in the DSM, and the estimation of the height of bare-earth points. Such studies have long been topic for researchers around the world (Krauss et al., 2011). Slope-based techniques use height change of local points and assume non-ground points which have larger slopes

(Debella, 2016; Vosselman, 2000). Geodesic dilation approaches generate morphology reconstruction for filtering non-ground areas (Vincent 1993; Arefi et al., 2011).

In many studies, the process for generating DTM from aerial laser scanning (ALS) data has been established, and some have been conducted to apply for DSMs acquired from optical images. However, DTM generated using only sparsely distributed ground points includes relatively errors, as most techniques are difficult to find the ground points that exist in areas such as dense forest canopy.

Our methods focus on the DTM generation process that is particularly appropriate for DSMs, which are derived as result of photogrammetric based image matching of high-resolution satellite images. Low-resolution global DTM is used as an add-on to provide the topographic information. This will be the basis for areas where there are few ground points in the DSM. The reason for applying KOMPSAT-3A optical images is because the imaging sensor can obtain panchromatic images with about 0.55m spatial resolution, which is similar that of CAS500. This allows us to predict the quality of the 3D information produced from images acquired with CAS500.

2. METHOLOGY

In the optical image derived DSM, it is not possible to match on some sides of an object whose height changes due to the occlusion present in stereo images. The height at that point is estimated from neighborhood points. Inevitably, the DSM includes smoothing part in the building boundary, which causes ambiguous difference between ground and non-ground objects.

As a way to overcome this limitation is to utilize an initial nDSM by additional use of the low-resolution DTM, which has roughly eliminated the impact of the terrain present in the DSM. First, bilinear interpolation is performed on the low-resolution DTM to convert to raster data with the same spacing as the DSM. Using the average difference within the 3x3 search window the deviation trend of local range is analyzed. The non-ground areas are explored by conducting geodesic dilation on the initial nDSM. If the grid value of the result is above the threshold, we define it as a non-ground area (Arefi et al., 2011).

The non-ground areas are classified into buildings and tree canopies. An area is assumed to be a building if there are sudden height changes at the boundary. If the extracted building area is too small or large, it is classified as a tree canopy with the remaining non-ground areas.

Next, the ground height for each classified area is estimated. In the building area, the original values present in the DSM are removed, and the ground heights are estimated from the result of IDW interpolation. For area classified as tree canopy, the height value of the DSM is offset derived from the initial nDSM. When the estimation process is completed for all grids, median and gaussian filter are applied with patch size 15 to remove outliers on the DTM.

3. RESULT

3.1 Dataset

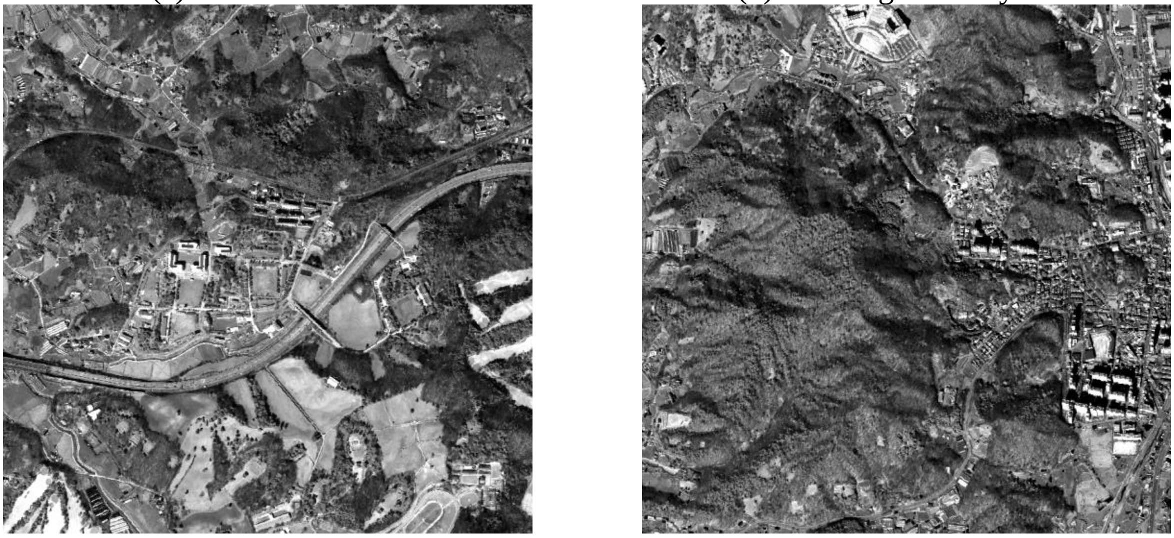
KOMPSAT-3A stereo images were used to test DSM and DTM generation. The stereo images captured Goyang area in South Korea and had spatial resolution of about 0.66 meters. The acquisition parameters of each image are shown in the Table 1. The target sites were selected four regions with an area of 2 km x 2 km, which reflect various topographic characteristics covering urban, rural, and steep terrain. An overview of the target sites is shown in Figure 1. The stereo images were processed for generating DSM with 2 meters GSD through multi-dimensional relaxation (MDR) method which is photogrammetric based matching technique (Rhee et al., 2018). Each site ranged from 17 to 512 meters.

Table 1. The acquisition parameters of stereo images

Product ID	Acquisition Time	Roll tilt (Deg.)	Pitch tilt (Deg.)
K3A_20170223044142_10582_00075117_L1R	04:41:48	1.9426	-19.7528
K3A_20170224043127_10597_00078297_L1R	04:31:33	-21.8882	-10.0158

The SRTM version 3, produced by NASA, was chosen for low-resolution DTM as initial terrain information. This global DTM had spatial resolution of 1 arc-second, about 30 meters. For quantitative evaluation, a manual DTM was employed as a reference data, which were offered from NGII in South Korea. The data has 5 m spacing with orthogonal heights based on EGM2008 geoid model.

(a) Mountain area (b) Building and hilly area

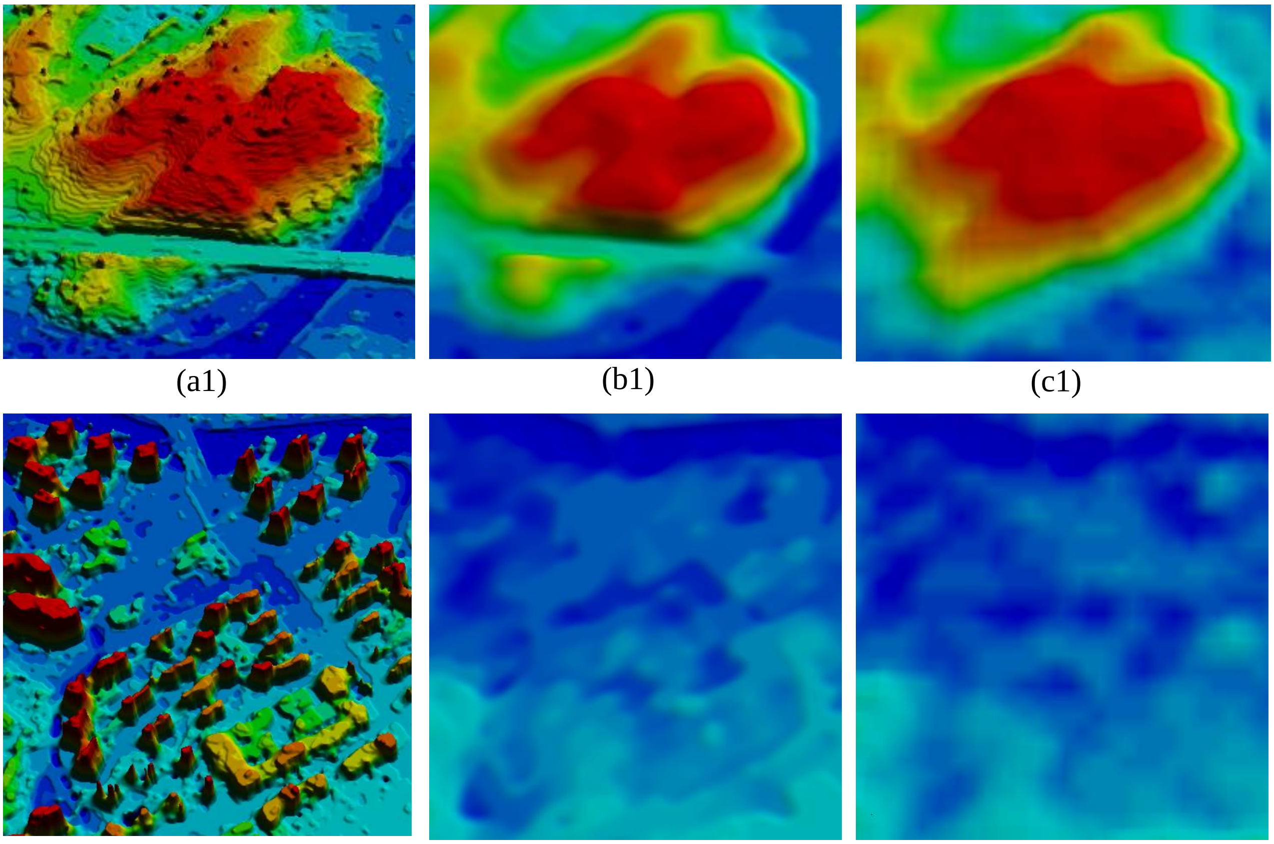


(c) Flat area (d) Complex area

Figure 1. Target sites

3.2 Proposed DTM

For visual comparison of DTM generated by the proposed method, two areas are shown in detail in Figure 2. In the Figure 2, (a) is a DSM derived from stereo images, (b) shows DTM produced by the proposed method, and SRTM (c) used as a low-resolution DTM. As shown in the DTM (b1), the non-ground objects present in the DSM were removed and the tree canopies were shrunken. Further, there is a clear difference between the generated DTM and SRTM. The DTM well reflects the shape of the surface obtained from satellite images, and it shows an improved quality compared to SRTM. In addition, Figure 2 (b2) presents that our method could remove the artifacts in building area (a2).

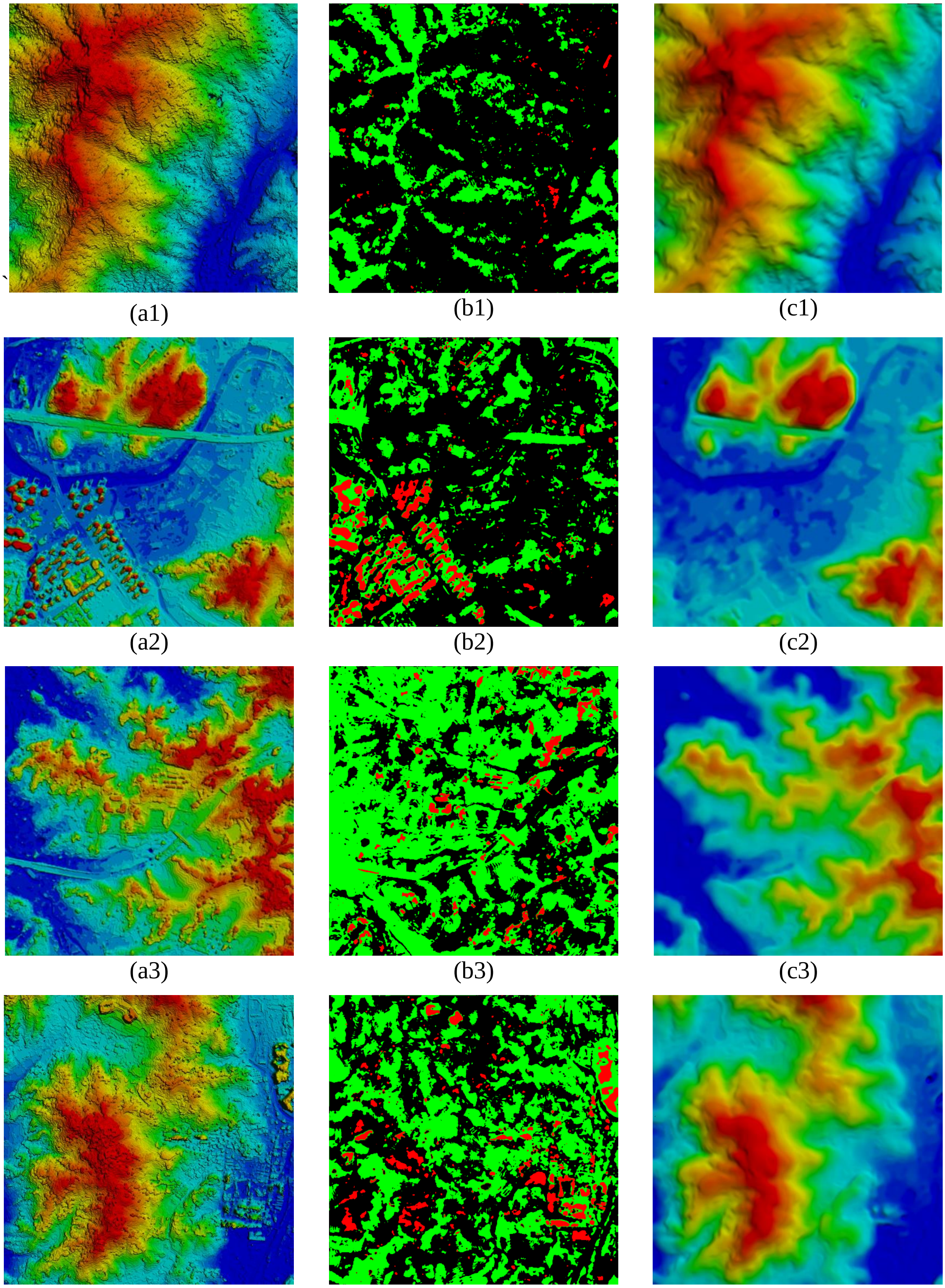

(a1) (b1) (c1)

(a2) (b2) (c2)

Figure 2. 3D view of the height models (a: DSM, b: DTM, c: SRTM)

Figure 3 shows the input DSM used in the DTM generating process, the non-ground classification map and the DTM result for four different target sites. To quantitative analysis, the accuracy of DTMs generated by proposed method were calculated. The deviations of the height value of the DTM and SRTM against reference DTM were compared to ensure that the proposed method could improve the accuracy. The sites chosen were mountainous, residential area with high-rise buildings, a flat area, and a complex terrain, in order.

As shown in the Table 2, the accuracy of DTMs were improved over SRTM at all four sites. On target site 1, a steep mountain terrain, the mean error and standard deviation of the low-resolution DTM were 8.45 meters and 4.88 meters, respectively. On the other hand, as shown in Figure 3 (b1), since the areas classified as tree canopy was relatively small, the proposed DTM reflecting the exact ground height of DSM had better accuracy compared to the row-resolution DTM. For the site 2, as in site 1, the ground points were separated well. In addition, buildings with large height differences had been successfully removed. The standard deviation was also low (1.85 meters). For the site 3 and 4, the proposed DTM showed relatively low accuracy. Figure 4 shows that large errors existed in the tree canopy area in site 3. In the processing of tree height, the error in SRTM affected the ground height estimation. Figure 3 (c3) displays that the hill shape in the DSM (a3) was not preserved well in DTM.


(a1) (b1) (c1)

(a2) (b2) (c2)

(a3) (b3) (c3)

(a4) (b4) (c4)

Figure 3. The input data and result in each target site (a: DSM, b: classification map, c: DTM)

Table 2. The accuracy of DTM and SRTM in each target site

(m)	Site 1		Site 2		Site 3		Site 4	
	Proposed	SRTM	Proposed	SRTM	Proposed	SRTM	Proposed	SRTM
Mean	3.30	8.45	3.70	5.82	5.29	6.23	6.61	7.52
Std.	3.07	4.88	1.85	3.65	2.62	3.61	3.08	4.24
RMSE	4.51	9.76	4.13	6.87	5.91	7.20	7.29	8.63

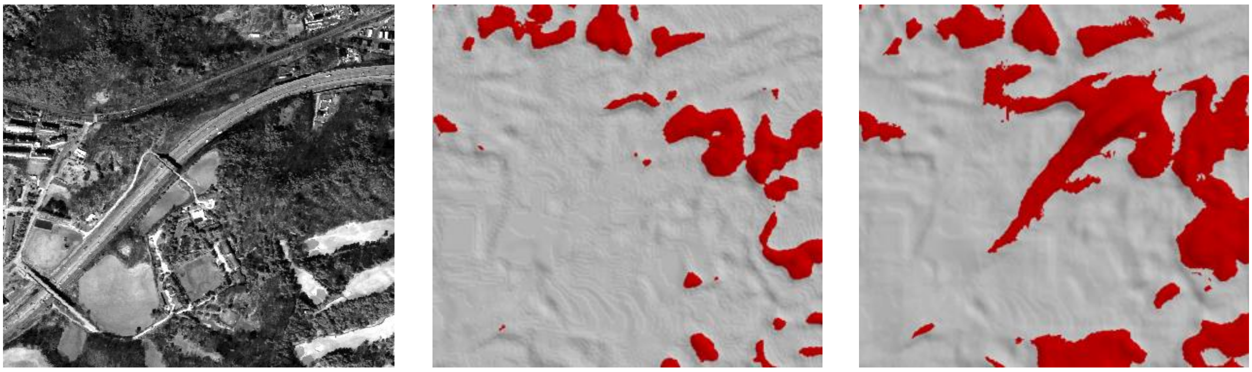

(a) Image (b) Proposed DTM (c) SRTM

Figure 4. The region of low accuracy in target site 3

4. CONCLUSION

This paper proposed a method of utilizing low-resolution DTM to generate high quality DTM using the 3D spatial information acquired from high-resolution satellite images. The proposed method was tested using DSM and SRTM which is global low-resolution DTM. The DSM was generated from KOMPSAT-3A stereo images by applying photogrammetric image matching technique. In the result of the experiment, the proposed DTM showed better vertical accuracy than SRTM. Using external data, it was possible to estimate ground height and generate improved DTM in tree canopies and urban areas, over which finding ground points is difficult. The result of DTM over various topographic characteristics found that the sites including many areas classified as tree canopy did not significantly improve the vertical accuracy. In the processing of tree canopies, the proposed method used the height values derived by SRTM to estimate the ground height. It seems that the erroneous values from SRTM have affected the accuracy of the proposed DTM. Therefore, we expect that the accuracy of the DTM will be greatly improved by using not only SRTM but also height values of high-quality DSM when estimating the ground height of tree canopy. In the future, we will perform follow-up experiments to estimate height offset of tree canopy region by using the high-quality DSM.

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