PERFORMANCE VALIDATION OF HIGH RESOLUTION DIGITAL SURFACE MODELS GENERATED BY DENSE IMAGE MATCHING WITH THE AERIAL IMAGES

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ABSTRACT:

The digital representation of the Earth surface in three dimensions (3D) has vital importance in wide range of applications such as urban planning and management, disaster monitoring, agriculture, forestry and hydrology. The digital surface models (DSM) are the most popular products to determine visible surface of Earth which includes all non-terrain objects such as vegetation, forest, and man-made constructions. The airborne light detection and ranging (LiDAR) is the preferred technique for high resolution DSM generation in local coverage. The automatic generation of the high resolution DSM is also possible with stereo image matching using the aerial images. The image matching algorithms usually rely on the feature based matching for DSM generation. First, feature points are extracted and then corresponding features are searched in the overlapping images in this traditional approach. These image matching algorithms face with the problems in the areas which have repetitive pattern such as urban structure and forest.

The recent innovation in camera technology and image matching algorithm enabled the automatic generation of dense DSM generation for large scale city and environment modeling. The new pixel-wise matching approaches are generates very high resolution DSMs which corresponds to the ground sample distance (GSD) of the original images. The numbers of the research institutes and photogrammetric software vendors are currently developed software tools for dense DSM generation using the aerial images. The new generation software tools are requires to multi-core CPUs as well as the graphics processing units to accelerate DSM production. The European Spatial Data Research Organisation (EuroSDR) started a follow up initiative to evaluate ongoing development in image based high resolution DSM generation in February, 2013. This new approach can be used high resolution DSM generation for the larger cities, rural areas and forest even Nation-wide applications.

In this study, the performance validation of high resolution DSM generated by pixel-wise dense image matching in part of the Istanbul was aimed. The study area in Istanbul is including different land classes such as open areas, forest and built-up areas to test performance of dense image matching in different land classes (Figure 1).

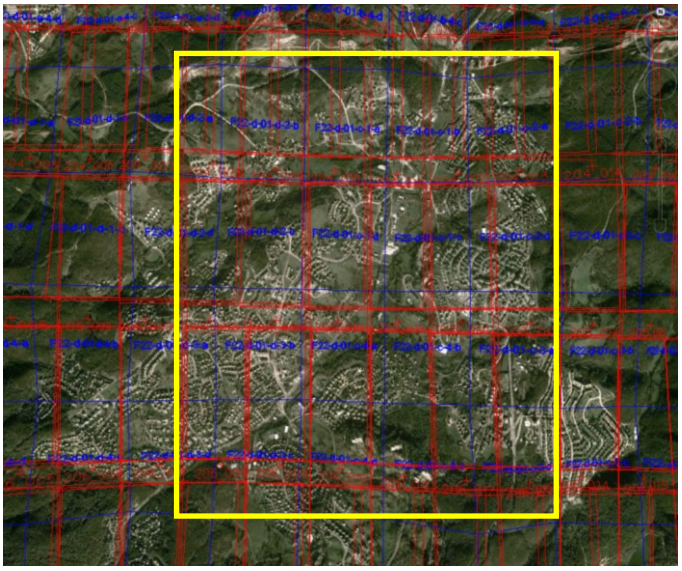
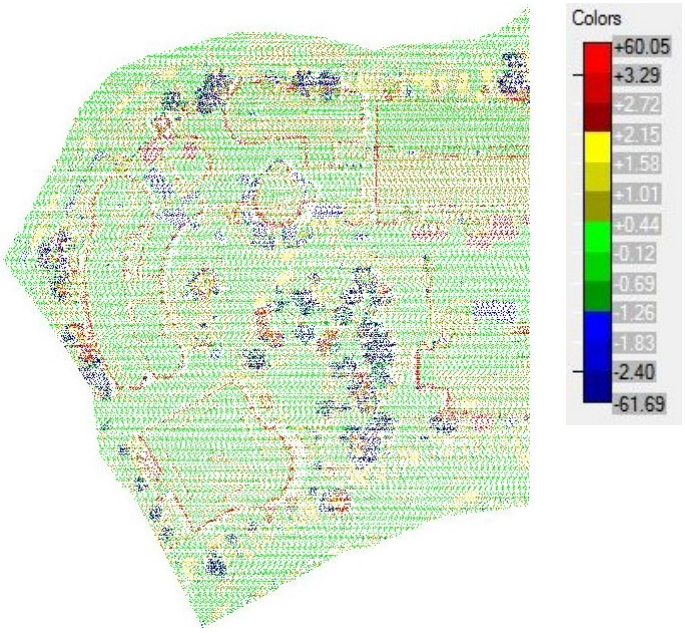


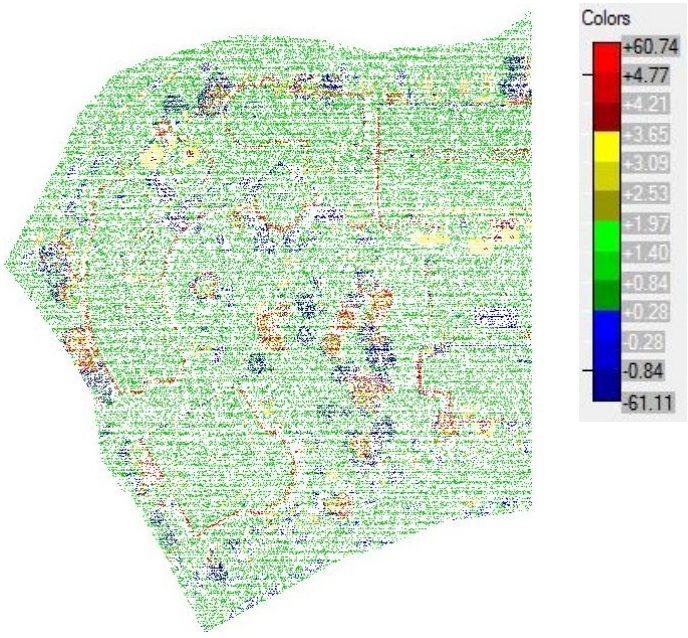
Figure 1. Test area in Istanbul.

This test actually is part of the Nation-wide dense DSM generation with point density 100pts/m^2 and true orthophoto generation project in Turkey. The Yildiz Technical University serves as consultant of Ministry of Environment and Urbanism of Turkey in this project. The aerial images were collected on September, 2013 over test area in Istanbul in Turkey with the UltraCam Xp aerial full frame camera in the context of the 1/1000 scaled photogrammetric map production project of Istanbul Metropolitan Municipality. The test sub-block was consist of the three overlapping strips with 18 images approximately 70% forward overlap and 35 % side-lap at GSD of 10 cm. The exterior orientation parameters of the images were acquired from bundle block adjustment of image block in the photogrammetric map production project. The high resolution DSMs of the test area at a density of 100 pts/m2 was generated with the German Aerospace Center (DLR)'s own developed software as a research institution and Microsoft UltraMap V3.1. commercial photogrammetric software. For performance validation of high resolution DSM of the test area, available LiDAR points have a density of 16 pts/m^2 acquired from Istanbul Metropolitan Municipality have been used as a reference surface.

The elevation differences between the high resolution DSMs from dense image matching and LiDAR were computed for selected open areas, forest and built-up areas in the test site. The differences are depicted in Figure 2 for urban area. Table 1 shows the standard deviations and root mean square errors (RMSE) of differences for all selected areas. The differences larger than three sigma were eliminated and the root mean square errors (RMSE) and standard deviations of differences were recomputed (see Table 2).



(a)



(b)

Figure 2. The computed elevation differences for DLR DSM (a) and UltraMap DSM (a) in urban area.

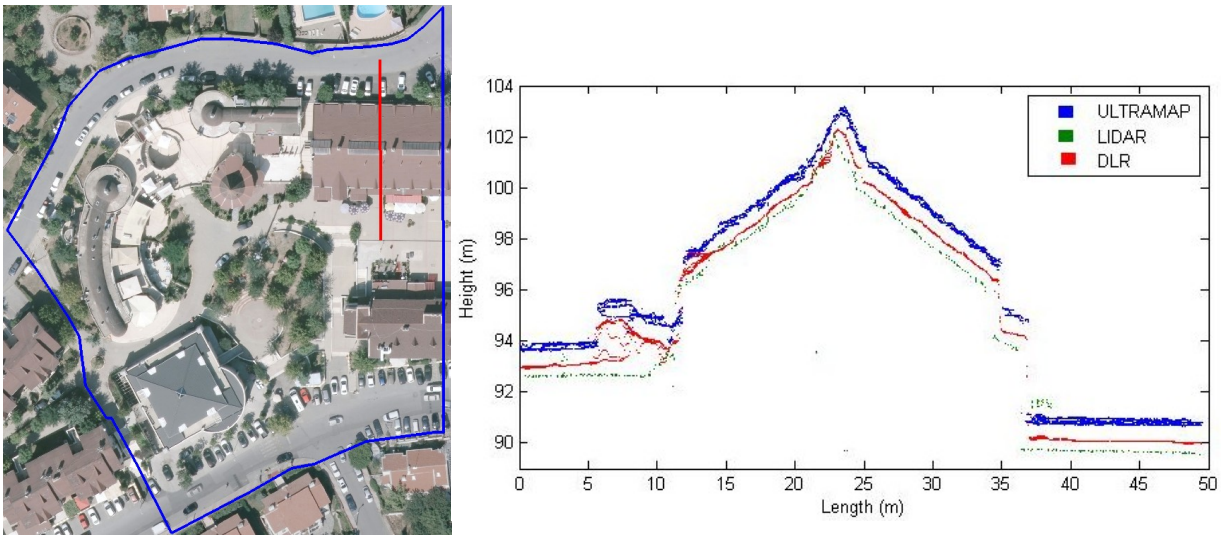
Land classes	DLR DSM		UltraMap DSM	
	Standard deviation	$RMSE_Z$	Standard deviation	$RMSE_Z$
Open area	0.96	0.983	0.906	1.332
Urban Area	2.074	2.088	2.008	2.325
Forest	5.382	6.177	4.552	5.563

Table 1. Standard deviations and root mean square errors (RMSE) of differences for selected areas

Land classes	DLR DSM		UltraMap DSM	
	Standard deviation	$RMSE_Z$	Standard deviation	$RMSE_Z$
Open area	0.316	0.431	0.347	1.048
Urban Area	1.597	1.610	1.487	1.802
Forest	4.613	5.322	3.812	4.807

Table 2 Standard deviations and root mean square errors (RMSE) of differences for selected areas after elimination differences higher than 3 sigma

In order to further quantitative analyses of the DSM differences, elevation profiles were extracted for selected areas. In Figure 3, the profile line overlaid to orthoimages (3a) and elevation profiles extracted from LiDAR as reference, DLR DSM and UltraMap DSM (3b) is given for urban area.



(a) (b)

Figure 3. The profile line overlaid to orthoimages (a) and profiles extracted from LiDAR, DLR DSM and UltraMap DSM (b)

The obtained result from this performance validation in Istanbul test area showed that, high resolution DSM which corresponds to the ground sample distance (GSD) of original aerial image can be generated successfully by pixel-wise dense image matching using commercial or research institution's software. The high resolution DSM at GSD of 10 can be produced Nation-wide for true orthophoto generation, 3D city model generation and various applications.