Semi-Automatic Technique for 3D Building Model Generation

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Key words: DTM, DSM, 3D Building Model, Phoogrammetry, Remote Sensing.

SUMMARY

Three Dimensional Building models are excessively used in various applications. Digital Surface Model is the back bone of the 3D building modeling. The automatic DTM generation techniques are not adequate for the built-up areas. The manual 3D digitization of the stereo images is time consuming. Establishing a semi-automatic technique for the 3D building modeling is required.

The main goal of this research is to establish a new semi-automatic technique for 3D building models based on the automatic DTM generation engines and the 2D vector representation of the buildings. The aim of this paper is to assess the established semi-automatic building model generation technique. Comparing the new technique output to the manual ones are performed for accuracy assurance.

This technique is applied to aerial photographs for low buildings in a village area, as well as stereo Ikonos images for high buildings in a city area in Egypt.

This study shows that the Automatic DTM Extraction modules do not represent neither the terrain nor the Buildings in an appropriate manner. However, the Semi-automatic DSM generation technique that introduced in this paper is more accurate in the building representation, as well as, it has accuracy within 1.0m in height..

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1. ABSTRACT

Three Dimensional Building models are excessively used in various applications. Digital Surface Model is the back bone of the 3D building modelling. The automatic DTM generation techniques are not adequate for the built-up areas. The manual 3D digitization of the stereo images is time consuming. Establishing a semi-automatic technique for the 3D building modeling is required.

This paper introduces a new semi-automatic technique for 3D building modelling depending on the automatic Digital Elevation models and 2D vector representation of the buildings. The aim of this paper is to assess the established semi-automatic building model generation technique. Comparing the new technique output to the manual ones are performed for accuracy assurance.

This technique is applied to aerial photographs as well as high resolution stereo satellite images (IKONOS Images) for different areas in Egypt.

2. INTRODUCTION

The 3D building models have been used in a numerous applications that required, beside the planimetry position, the elevation information of the objects on the ground, such as; communication, military, transportation, utilities, … etc.. Communication and urban planning are the most common applications that require the 3D building data.

The 3D building model is a digital representation of the real built-up areas with three dimensional coordinates (x, y, and z). When the digital elevation data describe the surface of the terrain with or without vegetation, it is called digital terrain model (DTM). However, when these elevation data represents not only the terrain surface but also the non-ground objects that exist on the terrain surface (usually man-made objects) then it is called digital surface model (DSM).

DSM is a 2.5 dimensional data, where each point (represented by x and y values) has only one elevation value (z). When the edge of a high object lies inside a pixel, the pixel has an average elevation value between the ground and the object's top elevations. Thus, the objects heights are not represented well as they are in the reality. Consequently, the edges of the buildings are not represented correctly, as the pixels that represent the building borders have transition elevation values between the roof and the ground surface surrounding the buildings. Therefore, when DSM is used for representing the 3D building model, the elevation values of the roofs of the buildings has to be used instead of the terrain elevation values. In other words, a reconstruction of the non-ground objects (with their correct shape and elevation) on the

actual ground surface (DTM) is required. Thus, a combination between digital terrain model and the object model has to be developed to create this accurate 3D building model.
The main goal of this research is to establish a new semi-automatic technique for 3D building models based on the automatic DTM generation engines and the 2D vector data (obtained from the orthogonal images).

3. DSM GENERATION TECHNIQUES

Several techniques for generating the digital surface models have been developed, some of these methods are simple and fast and others are more complex and time consuming. The available techniques for producing DTM can be summarized as follows:

3.1 Digitization of Existing Topographic Maps

Extracting the elevation information from existing topographic maps can be performed by digitizing the contour lines and/or spot heights. Then using one of various interpolation techniques to get the elevation data to points between the contour lines, the DTM can be generated. This method can be considered as one of the fastest, as well as, least expensive methods. Inversely, the output accuracy depends on the quality, scale, and accuracy of the digitized maps as well as the professionalism of the digitization operator and his/her accuracy. Nether the less, the generated model will describe the terrain data only, since the elevation data about the non-ground objects are not included in the Topographic maps.

3.2 Ground Survey Techniques

Using the tachometer instruments; such as Total Stations, elevation information can be obtained. This is a traditional method which is called ground survey. By this method, the X, Y, and Z coordinates of any point, which lies on the line of sight of the base point, can be measured. Usually, this method is used for acquiring data about the ground elevation through grid lines with equal distance in between. Total Stations can be used for collecting position and height information about any other point.

GPS as a modern ground survey technique can be used as well for collecting three dimensional coordinates of points covering the area of interest. Then, using an interpolation technique, X, Y, and Z coordinates of grid points with constant distances can be calculated, and a DTM can be generated.

The ground survey methods produce high-resolution and accurate DTM but these methods are time consuming specially for large areas, and even small areas with a lot of details.

3.3 Active Remote Sensing Techniques

The most popular active sensors that are used in remote sensing are radar and laser scanner altimeter. These two sensors can be used for 3D coordinates acquisition of points on the ground, and hence, a DSM generation.

In Radar images, based on two different passes or two different antennas mounted on the same platform, the phase information can be calculated depending on the obtained information from the slight offset of the two emitted microwaves. By measuring the range difference of the two backscattered waves received at the antenna, the elevation of the ground or the objects on the ground can be determined relatively to the position of the sensor. However, since the position of the sensor, at the moment of sending and receiving the signals, is accurately known, the absolute 3D coordinates of the whole area of interest can be determined. Digital surface model can be generated from the obtained data. Since the Radar images are low resolution, the generated DSM is, consequently, will be with low resolution.
Laser Scanning technique is a ranging system as well. The system, mounted on board of an airplane, sends pulse signals to the ground and receives the reflected signals. Since the light (Laser Pulses) velocity is known, by measuring the difference in time between sending and receiving signals, the relative distance between the sensor and the ground point can be determined. Knowing accurately the position and altitude of the laser system at the moment of sending pulses, the position of the points on the ground can be calculated precisely. This technique is a blind system, which required auxiliary data for better interpretation, such as digital or video camera.

3.4 Photogrammetric Techniques

Photogrammetry techniques are, and will still, the most common techniques for producing topographic maps and generating digital terrain models. Based on rigorous mathematical models, such as Collinearity equation, and using a stereo pair of images (aerial photos or satellite images), the 3D coordinates of the surface points can be determined. Presently, digital Photogrammetry is common in several countries and there are several software programs that speed up the aerial triangulation process.

Photogrammetry can be considered as the most accurate technique for DSM generation, specially if there are qualified technicians who are able to digitize objects in three dimensions using the stereoscope, or the equivalent instruments. However, this manual technique is time consuming specially in the built-up areas.

There are various software packages have the capability for automatic terrain extraction using matching techniques, which, significantly, reduces the time and effort for generating DTM of large blocks. However these techniques generate poor DSM, which is not accurate in built-up areas.

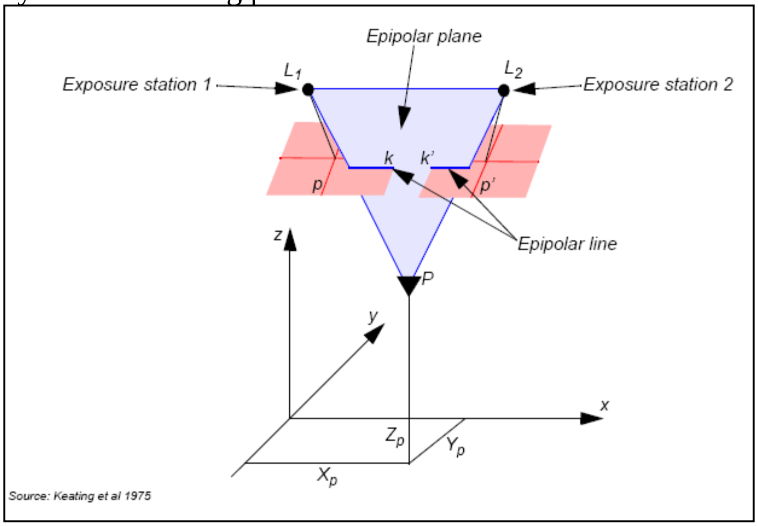
4. AUTOMATIC TECHNIQUE FOR DSM GENERATION

Rather than manually collecting individual 3D point positions with GPS or using direct 3D measurements on stereo imagery, automated techniques extract 3D grid points as representations of the Earth’s surface in the overlap areas of two images. This is referred to as automated DTM extraction. Usually, the generated surface model is in raster format with constant pixel size, resolution or grid points with equal intervals.

The DTM from stereo images can be extracted automatically in a three-step process. These steps are: Digital image matching, ground point coordinates determination, and DTM construction.

4.1 Digital Image Matching

Matching is an important step in many applications such as; object recognition, stereo vision, 3D reconstruction, and tracking. Digital image matching techniques are used to automatically identify and measure the positions of common ground points appearing in the overlap area of the two adjacent images. Image matching depends on digital image correlation to find areas of similarity between the images in the overlap area. The correlation coefficient is used to represent the measure of similarity between the matched point pairs. The larger the correlation coefficient, the more similarity between matched point pairs exists. The geometric and radiometric characteristics of the stereo pair images are used as the major constraint of the image matching process to produce highly accurate and reliable matching image point pairs. The epipolar geometry for the stereo pair is used to constrain the search area used to find the matching point to any specified one, as shown in figure 1. Therefore, images in the stereo pair are re-projected to the epipolar projection. The epipolar images are created from the raw stereo images after elimination of errors in Y direction during image-to-image correlation (removing the Y Parallax). Using epipolar images in the extraction of a DEM improves the speed and reliability of the matching procedure.



Adopted from Imagine OrthoBase User's Guide

Figure 1. The Eppipolar Geometry

4.2 Ground Points Coordinates Determination

Once the automated DTM extraction process has been completed, a series of distributed 3D points is located within the overlap area. The 3D points are subsequently interpolated to create a raster DTM.

4.3 DTM Construction

The automatically extracted and calculated 3D points are used as a basis for constructing a DTM. Raster DTM output method creates a continuous surface. Conversely, ASCII files output method creates a discrete DTM surface.

The ERDAS OrthoBase package is used as the automatic DTM extraction engine in this paper.

These techniques generate automatic DTM fairly accurate for the bare terrain, however, for built-up areas, matching techniques provide unacceptable results.

5. SEMI-AUTOMATIC TECHNIQUE FOR DSM GENERATION

To produce digital surface model, there are different automatic and semi-automatic algorithms. The adopted comprehensive method is through digitizing the buildings with their true elevations, and then generates the DTM while obscuring the buildings areas. Next, the obscured areas are filled with elevation data by interpolated values according to the ground elevations surrounding the obscured areas. However, this method goes as series steps, which is time consuming. Therefore, a semi-automatic DSM generation technique is performed. This technique is described as illustrated in Figure 2; it depends on the automatically generated DTM and the manually digitized 2D buildings. Then a combination of the two outputs can be used in producing the DSM. This technique saves time and effort, as it does not require specialists in stereo visualization.

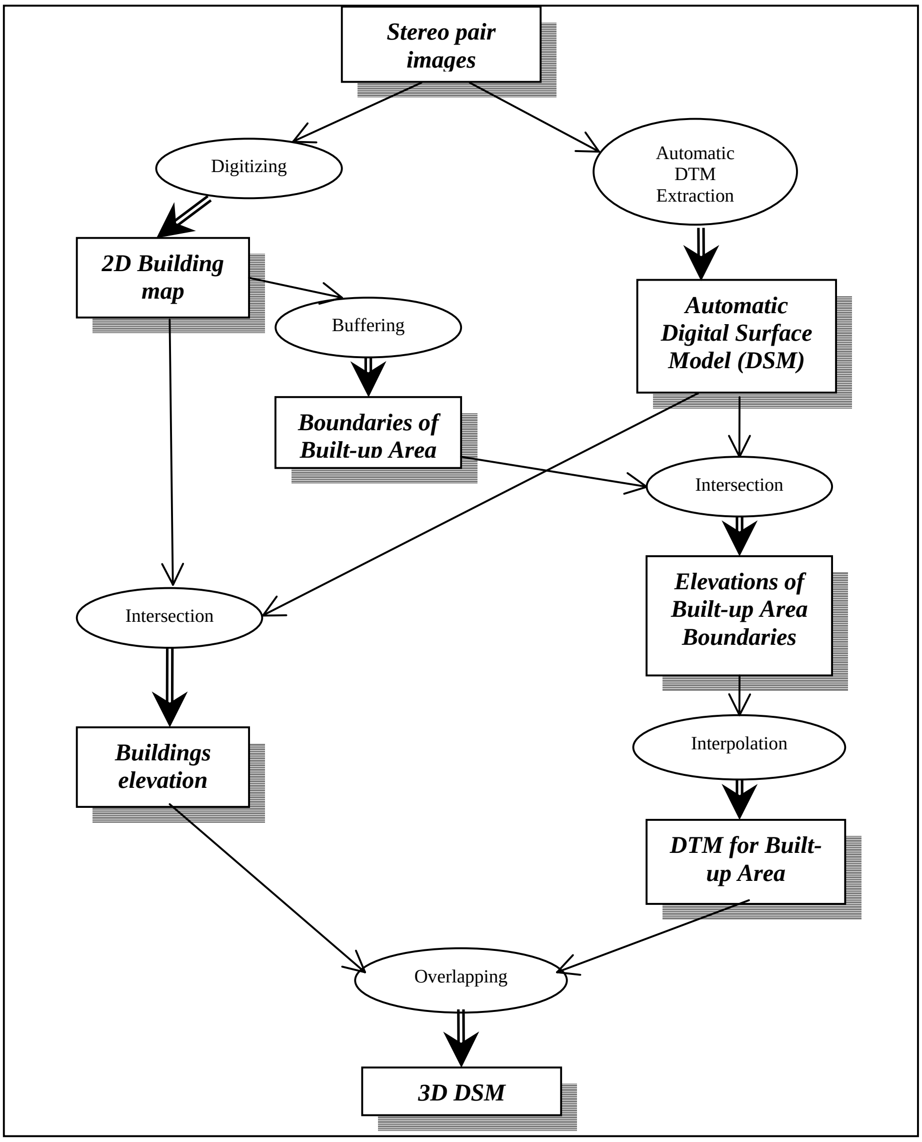


Figure 2. Description of the DSM generation Technique

A computer program has been written to semi-automate the process of converting the automatic extracted digital elevation model to a realistic digital surface model, as shown in the flow chart of DSM generation process. The steps of that procedure are:

1. Digitize buildings inside the study area manually from the less tilted image.
2. Collect tie points on the roof of the buildings and generating the automatic DTM.
3. Overlap the digitized 2D buildings and the automatic generated DTM, the output buildings' roof elevation may not be constant within the buildings depending on the values of the DTM.
4. Use the neighbourhood function each building get one constant value equals to the maximum value within the building.

5. Buffer the built-up areas towards outside, and exclude these areas from the automatic DTM, to eliminate the non correct elevation values, and determine the elevation values of the boundaries of the buffered zones.
6. Fill the buffered zones by the average elevation values of the boundaries to create a new DTM, hence, the inaccurate elevation values will be eliminated.
7. Combine the building elevation file with the DTM only file to form the actual DSM. (Reconstructing buildings and non-ground objects on the new DTM)
8. Use the elevation values of the tie points (on the roof of the buildings) to check the constructed DSM.

6. EXPERIMENTAL WORK

The performed semi-automatic technique for DSM generation has been applied on two different datasets; one stereo model of aerial photograph for part of a village (with low buildings), and a stereo IKONOS satellite images for part of a city (with high buildings). Figure 3 shows the areas of interest in the two datasets; a) Village aerial photograph, and b) city satellite image.

a b

Figure 3. Study area

The triangulation of the stereo images is out of the scope of this paper, therefore the rectified images have been used.

for applying the procedure described earlier in this paper, the ERDAS Imagine Orthobase is used for automatic DTM generation. ArcMap is used for onscreen digitizing of the buildings in the study area, and buffering the buildings to eliminate the incorrect DTM data, and ILWIS is used for performing the rest of the processes for generating the DSM.

- Figure 4 illustrates the collecting tie points step on the roof of the buildings.

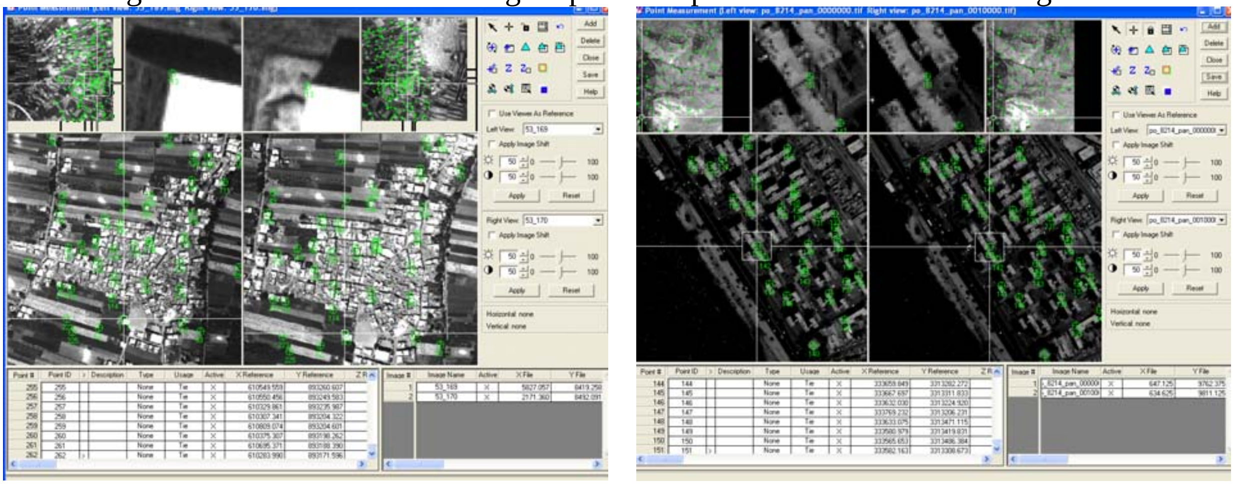


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Figure 4. Collecting tie points

- The automatic DTM generated by orthoBASE package is shown in Figure 5.

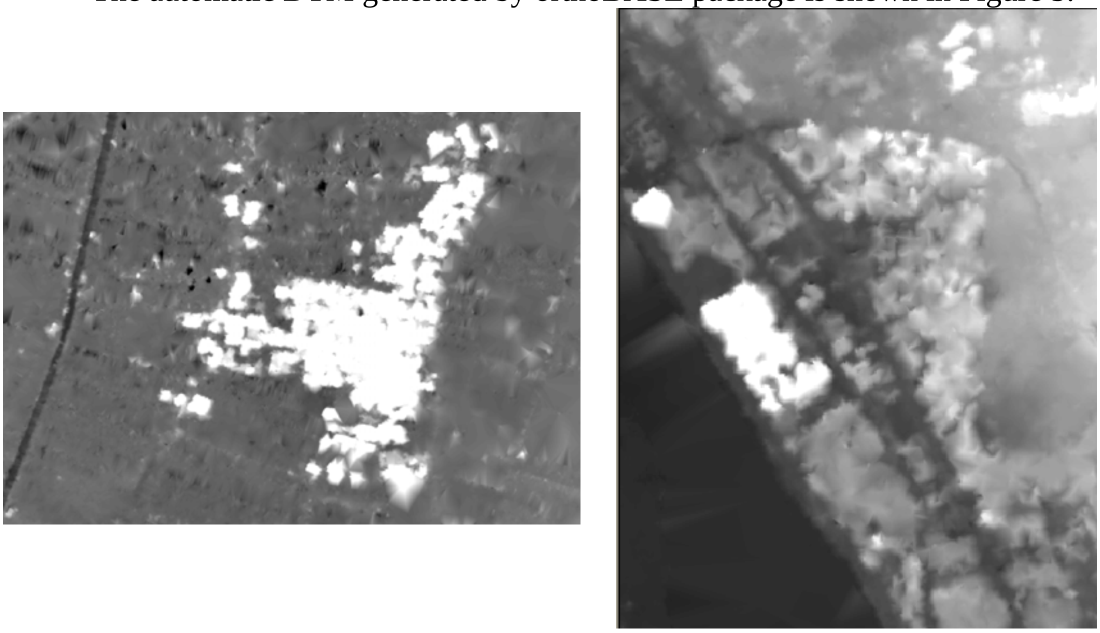

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Figure 5. Automatic Generated DTM

- For both datasets, using one of triangulated images (the less tilted one) to digitize, manually, the buildings inside the study as 2D vector data, Figure 6.

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Figure 6. 2D digitized buildings

- Determine true building elevations by intersecting the digitized buildings file with the automatic DTM file, and then give each building the maximum elevation value within the building itself, Figure 7.

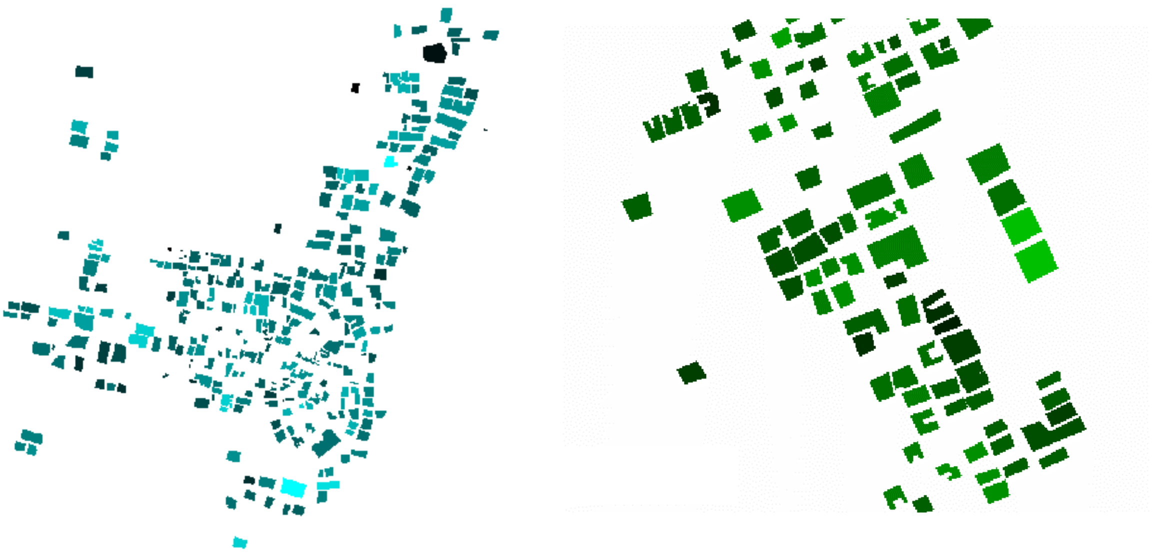

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Figure 7. Buildings with true roof elevations

- Buffer the built-up areas towards outside, to eliminate the non correct elevation values data.
- Fill the buffered zones by their average elevation values to create a new DTM, hence, the inaccurate elevation values will be eliminated, Figure 8.

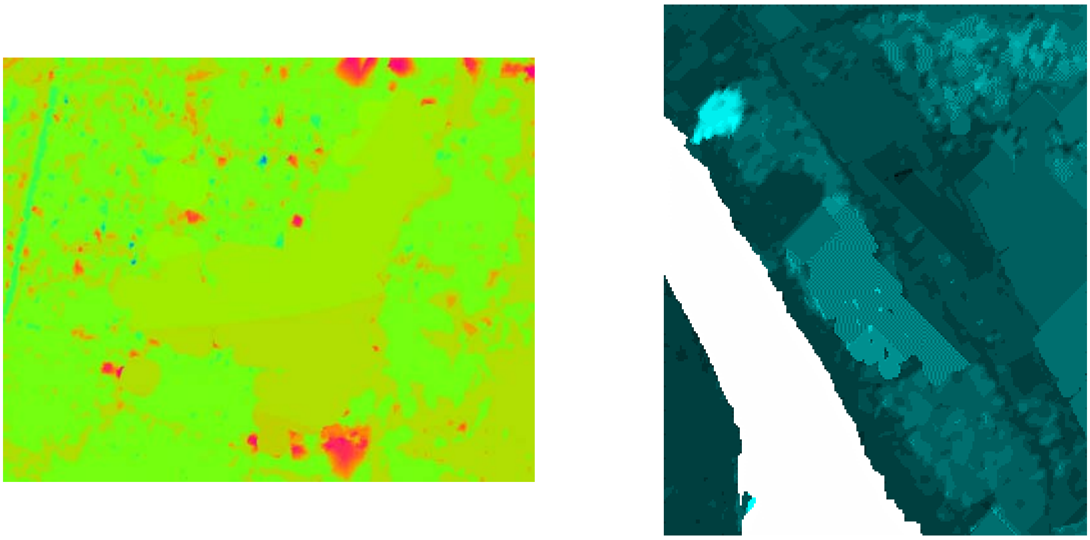

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Figure 8. Extracted DTM

- Reconstructing buildings on the new DTM, Figure 9.

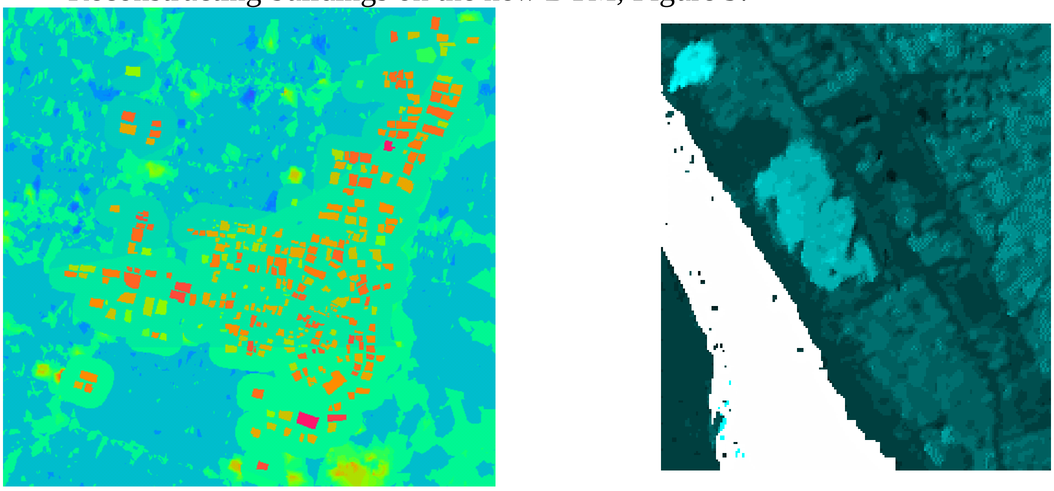

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Figure 9. Final DSM for the Study Area

- Finally the DSM is generated in a semi-automatic technique, and the values of the building heights are used to check the produced DSM, Figure 10.

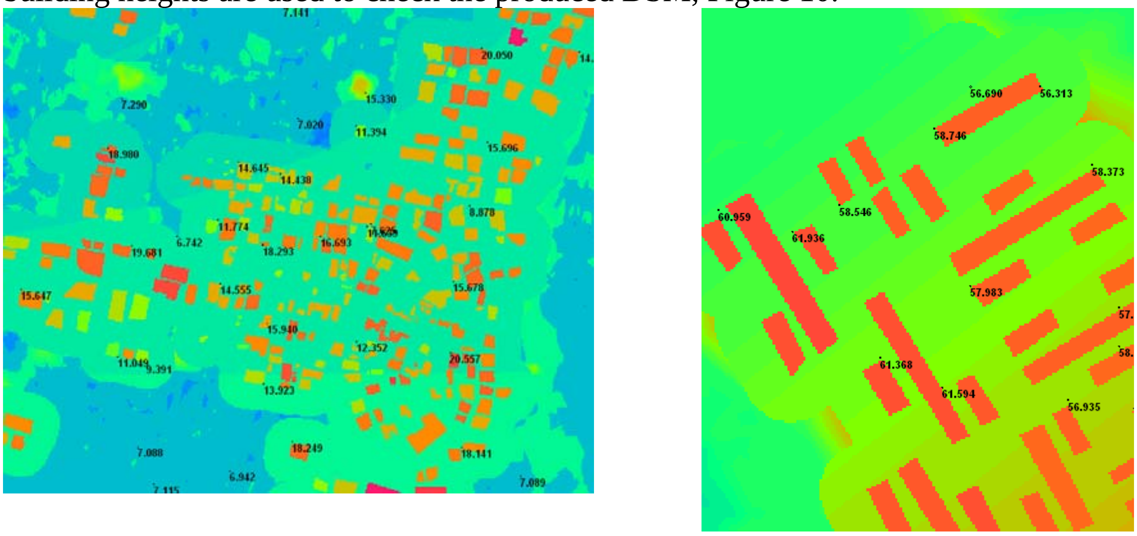

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Figure 10. DSM Evaluation step

By comparing the check points with the produced DSM it is found that the difference between the check points and the produced DSM values is within 50 cm in the low buildings and aerial photographs case, and within 1.0 m in the case of satellite images and high buildings.

7. CONCLUSIONS

According to this study, the most comprehensive conclusions can be summarized as follows:

1. Automatic DTM Extraction modules do not represent urban areas correctly.
2. Semi-automatic DEM generation technique can be used for DSM development for better representation of 3D surface models (specially for buildings and sharp-edge objects representations).

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