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Assessment of the Automatic Digital Surface Model from Digital Aerial Camera and from Lidar Point Clouds Data

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Abstract

The advent of very high resolution digital airborne camera capable of producing stereo images led to a new era in extracting digital Surface model. Until recently, the collection of high quality digital surface models was assigned to the use of airborne lidar. The aim of the research is to evaluate the potential of digital photogrammetric aerial camera and Airborne lidar for the generation of accurate digital surface Model (DSM). The first part of the paper is focused on DSM generation from digital photogrammetric aerial camera. The second one is concerned with the airborne lidar DSM generation. In DSM generation from digital photogrammetric aerial camera, Firstly, image orientation, AT have been performed. Then automatic digital surface model DSM generation from digital aerial camera has been performed using image matching. Leica Photogrammetric Suite (LPS) module of Erdsa Imagine 2014 software was utilized for processing. In DSM generation from LIDAR las point cloud, DSM was generated from LIDAR las point cloud using open source software lastools. Then the accuracies of the generated DSM's from both techniques were compared. The results show that automatic digital surface model DSM that has been produced from digital aerial camera gives high density 3D point clouds compared to the LIDAR 3D point clouds. It was found that the DSM produced from LIDAR is better accuracy than the DSM produced from digital aerial camera.

Key words: Point clouds- LIDAR- Digital photogrammetric camera – digital surface model (DSM)- Digital photogrammetry- image Matching.

INTRODUCTION

DEM generation from any data source such as Lidar data, digital aerial images is crucial for a variety of mapping applications for examples, ortho-photo generation, city modelling, object recognition, creation of perspective views and telecommunications (Habib et al., 2004).

The transition from passive systems such as aerial photography to active systems such as (RADAR, SAR, LIDAR) offer the opportunity to collect data accurately and systematically over large areas. Light Detection and Ranging (LIDAR), is an emerging technology, provides the possibility of acquiring high dense three dimensional point clouds (X,Y,Z) and the intensity data(I). In some cases, multiple pulses or full waveform signals can be captured by certain hardware systems (Zhang, 2005). Also high accuracy Digital Elevation Models (DEMs) can be generated in a fast and cost-effective way (Liu et al, 2007).

LIDAR is a mature remote sensing technology which can provide accurate elevation data for both topographic surfaces and above-ground objects (Yunfei et al.,2008).

LIDAR consists of three main components: (i) (GNSS), (ii) an Inertial Measurement Unit (IMU) and (iii), a Laser Scanner Unit. While the GNSS receiver is used to record the aircraft position, the IMU measures the angular attitude of the aircraft (roll, pitch and yaw or heading). The Laser Scanner Unit transmits pulses of light toward the surface of interest and records both Submitted 15/7/2018 the travel time of the laser beam and the energy which is reflected by the surface (Jochem ET AL.,2009).

A detector in the LIDAR sensor records the time it takes each laser pulse to travel from the sensor to the reflective surface and back to the sensor. Since the speed of light is a constant so that we can compute the distance from the sensor to the reflective surface.

LIDAR can capture a georeferenced 3D point cloud from both first and last echos. The LIDAR points being on the terrain are separated from points on buildings, trees and other object above terrain; Digital Surface Model (DSM) and Digital Terrain Model (DTM) can be derived easily and quickly (Rottensteiner, and Briese,2002; Wang and Hsu,2008).

The digital photogrammetry allows automated digital surface model production from any airborne, including Unmanned Aerial Vehicles UAVs platforms or satellite sensors. The photogrammetric workflow comprises of automatic modules for aerial triangulation (AT), DSM generation, DTM extraction, orthorectification and mosaic creation as well as manual editing tools (Rotenberg et al.,2013).

Digital photogrammetry era has also enabled new methods for elevation (DSM) extraction using automatic image matching technique (Demir et al.,2008). Airborne lidar produces high accurate digital surface models. With the increasing quality of digital airborne cameras as well as improvements in matching algorithms allow for an automatic image-based acquisition as a suitable alternative (Haala and Rothermel, 2012).

Matching algorithms, autonomous orientation of images by means of automatic aerial triangulation ease the use of photogrammetry and reduce the costs in digital maps production (Rinaudo ,2010). In this research the digital surface model DSM was produced from digital aerial camera and LIDAR point clouds.

2. Study area and data sets:

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Free sample dataset of down town Toronto / Canada, North America, kindly provided by the (ISPRS) –summer 2017. The aerial images were captured by the Microsoft Vexcel's UltraCam-D (UCD) camera and the LiDAR data were captured with Optech airborne laser scanner ALTMORION M. The area contains high-rise buildings.

Digital Aerial Images taken by UltraCam-D cover the downtown of Toronto which was operated and processed by FBS (First Base Solutions) company located in the Greater Toronto Area in Canada. The data consist of two images in strip 2 with 60 % forward overlap (images 03747, 03749).The images were taken from an altitude of 1600 m above ground. The total number of the images in the test area is 2 and the exterior orientation parameters are provided. The image size is 7500 × 11500 pixel and the pixel size is 9 µm, ISPRS provides the interior orientation parameters (IOP) and the and exterior orientation parameters (EOP). See table 2,3. The "Downtown Toronto" datasets also provides ALS data acquired by Optech. Optech flew over the "Downtown Toronto" area and acquired ALS data using Optech's ALTM-ORION M in February 2009 with the aircraft speed of 120 knots at the flying altitude of 650 m. The ALTM ORION M operates at a wavelength of 1064 nm (Near Infrared) and scans the underlying topography with a scan width of 20 degrees and the scan frequency of 50 Hz. The reflected echoes were digitized at a sampling rate of 100 kHz. The data set consists of 6 strips and point density is approximately 6.0 points/m^2. The ALS data provided is formatted in ASPRS's LAS 1.3 format and refers to the same coordinate system as the orientation parameters of the Ultra Cam-D images. In addition to the original ALS point cloud, a digital surface model (DSM) is provided.

Methodology:

1-Aerial image orientation, triangulation.
2- Generation of digital surface model (DSM) from digital aerial camera
3-Generation of LIDAR DSM.
4-Assessment of the accuracy of digital surface model (DSM).

3.1. Photogrammetric project creation:

Photogrammetric project creation means defining a project name, the reference coordinate system, datum, units, and the used camera for the project. A project was created to include digital camera images. Leica Photogrammetric Suite (LPS) module of Erdsa Imagine 2014 software was utilized for processing. , the datum and the projection were selected WGS84 and the UTM projection zone 17 respectively. Figure.1 shows the model configuration.

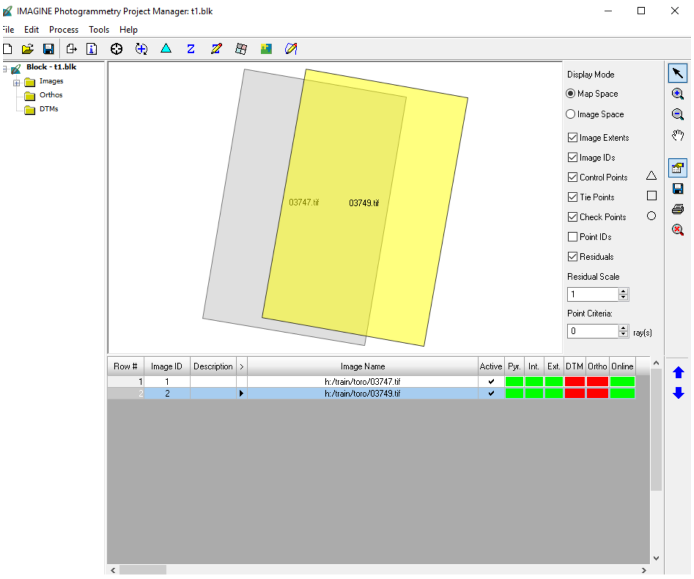

Fig.1: Model configuration.

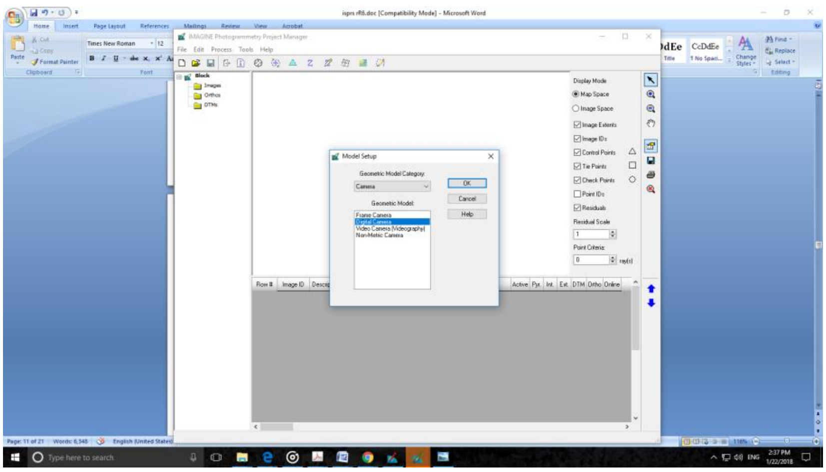

Fig. 2: Sensor definition.

3.2. Importing images:

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Importing images is the most complex data conversion process because it usually includes a file with a relatively large size. The technique to be used to import data depends on the type of the sensor that is associated with the imagery. Erdas Imagine 2014 was used for importing imagery. The following images were imported Figure 3.a and Figure 3.b.

3.3. Computation of image pyramids:

Pyramid layers are used to optimize image display and automatic tie point collection. Using this pyramid, image contents are preserved and computation times are reduced. Image Pyramids for the two images were computed.

3.4. Image Orientation:

ISPRS provides the interior orientation parameters (IOP) and the exterior orientation parameters (EOP). Interior orientation parameters and exterior orientation parameters were defined. The interior orientation parameters were defined for two images according to Table 2.

3.4.1. Interior orientation of the digital images:

Interior orientation parameters of the digital images were defined. Table 2 shows Interior orientation of the two digital images of the strip2.

Fig. 3a: 03747.

Fig. 3b: 03749.

Table 1: Summary of the configuration of the digital aerial camera images.

Strip2
03747, 03749

Table 2: Interior orientation of strip 2 digital images.

Camera	Strip	File coordinate system			Camera coordinate system			
		rowPP [mm] [pixel]	colPP [pixel]	f [pixel]	xPP [mm]	yPP [mm]	f [mm]	pixel size □ [mm]
Ultra Cam D	2	3750	5730	11266.67	0.000	0.000	101.400	0.009

3.4.2. Exterior orientation:

Aerial triangulation is the process of establishing a mathematical relationship between the images contained in a project, the camera or sensor model, and the ground. The information resulting from aerial triangulation is required as input for the orthorectification, DEM creation, and stereopair creation processes (Leica ,2006). Leica Photogrammetric Suite (LPS) module of Erdas Imagine 2014 software was utilized for defining exterior orientation parameters. The exterior orientation parameters were defined for the two images according to Table 3.

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Table 3: Exterior orientation of the digital images of the strip2.

Strip	Image file	Projection Centres			Rotation Angles (ω: primary, x; Φ: secondary, y; κ: tertiary, z)		
		X0 [m]	Y0 [m]	Z0 [m]			
2	03747.tif	629623.149	4834071.793	1634.685	0.04670	0.15983	-99.55331
2	03749.tif	630013.209	4834069.204	1632.655	0.06512	0.14967	-100.09653

3.5. Automatic tie points generation:

1-Feature selection in one of the scenes of a stereo-pair: Selected features should correspond to an interesting phenomenon in the scene and/or the object space.
2- Identification of the conjugate feature in the other scene: This problem is known as the matching/correspondence problem within the photogrammetric and computer vision communities (Habib et al., 2004).

Tie points were generated manually in the overlap area. The resulted RMS of triangulation was 0.22 m.

3.6. Digital surface model (DSM):

There are many criteria involve in applied technique for producing DSM like, image resolution, availability of attitude parameters, number and distribution of GCPs, morphology of study area and final DEM application (Deilami and Hashim,2011).

Digital surface model (DSM) includes any buildings, vehicles, vegetation (canopy and understory), as well as the “bare ground". To generate the required ’bare-earth DEM, ground and non-ground features/data points must be distinguished from each other so that the latter can be eliminated before DEM building (Kunapo ,2005) .

Figure.4 shows the resulted digital aerial camera DSM of Model 03747-03749. Figure.5 the used parameters.

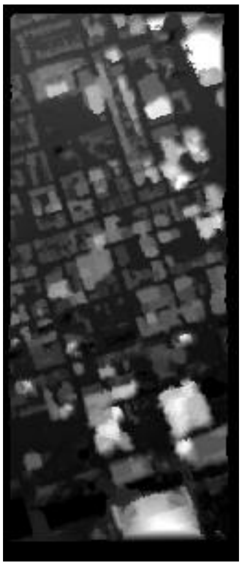

Fig. 4: The resulted digital airborne camera DSM of Model 03747-03749.

3.7. LIDAR Digital surface model (DSM):

Digital surface model (DSM) was generated from the merged file of las point cloud using lastool software. This is reflected from the surface of objects such as the soil, buildings, cars, leaves, and so on. The process aims to create a high resolution DSM interpolated from LiDAR point cloud data into a regular grid of 3*3 m cells. Lastool was used for producing the DSM.

The following parameters were used in Lastool software for producing DSM:

Grid size 3
Item elevation
Output .img
By classification of return First only

Figure.6 depicts Lidar DSM of the whole study area. Figure 7 illustrates the whole workflow.

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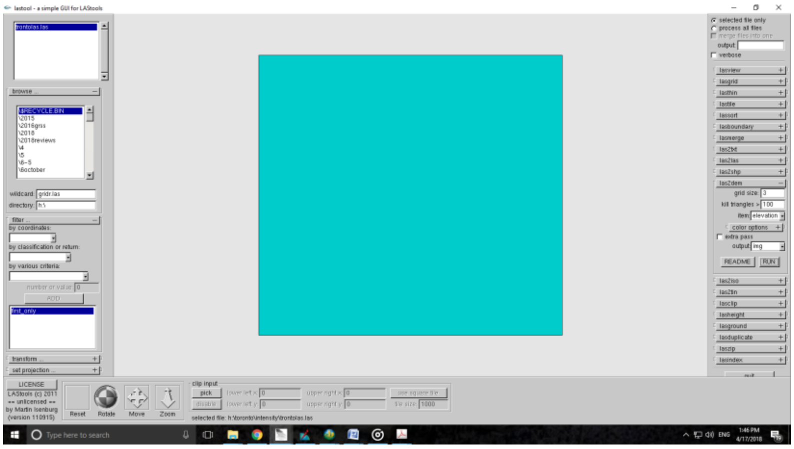

Fig. 5: The used parameters.

3.8.Validation using LIDAR data:

Check points extracted from automatic tie point generation were used for checking height of LIDAR DSM and digital aerial camera DSM.

$$R\hat{M}SE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\Delta h_i^2}$$

The results show that the vertical accuracy of automatic digital surface model DSM that been produced from digital aerial camera is 0.28 m.

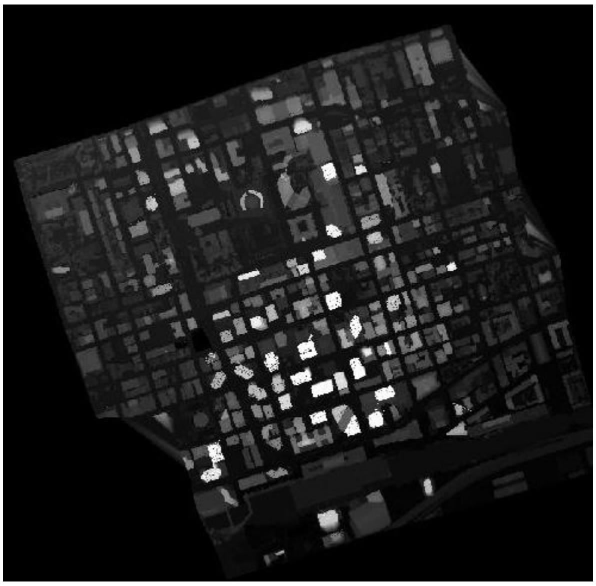

Fig. 6: Lidar DSM of the whole study area.

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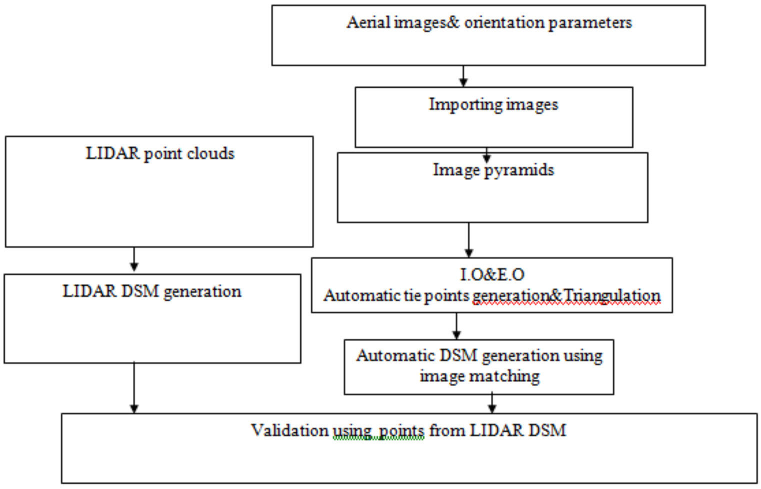

Fig. 7: The whole workflow.

It was found that LIDAR DSM is more accurate than digital aerial camera DSM.

RESULTS AND DISCUSSION

Digital images were processed in Leica Photogrammetric Suite (LPS) module of Erdas Imagine 2014 software. Firstly, image orientation, AT have been performed. The resulted RMS of triangulation was 0.22 m. Then automatic digital surface model DSM generation has been produced from digital aerial camera.

It was found that LIDAR DSM is more accurate than digital aerial camera DSM. The results show that the vertical accuracy of automatic digital surface model DSM that been produced from digital aerial camera is 0.28 m. Automatic digital surface model DSM generated from digital aerial camera gives high dense photogrammetric 3D point clouds compared to the LIDAR 3D point clouds.

Conclusions:

Leica Photogrammetric Suite (LPS) –Erdas imagine 2014 software has been used for producing DSM from digital aerial camera. The DSM generated from digital aerial camera and that generated from LIDAR point clouds were compared. The results show that the vertical accuracy of automatic digital surface model DSM that been produced from digital aerial camera is 0.28 m. Also, the results show that automatic digital surface model DSM produced from digital aerial camera method has very high density photogrammetric 3D point clouds compared to the LIDAR 3D point clouds. It is recommended to evaluate the accuracy of the true orthoimage produced from LIDAR DSM and digital aerial camera DSM.

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