EFFICIENT DIGITAL TRUE ORTHOPHOTO GENERATION

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ABSTRACT: In modern urban mapping, the digital orthophoto is an efficient product that is used to represent the correct shape of 3D objects. It represents the precise measurement similar to the map. In addition, digital orthophotos are becoming very popular within the GIS society. However, as orthophotos do not generally take into account the surface model in the rectification process, the buildings are distorted from their true locations. Generation of digital true orthophotos which is geometrically corrected building structure, by using a digital surface model (DSM) and considering occluded areas is the way to correct above mentioned problems. LiDAR offers one of the most accurate, expedient and cost-effective ways of capturing wide area elevation information to produce highly detailed digital surface model of the earth (DSM) which can be used for the generation of true orthophotos. Due the accuracy of true orthophotos strappingly depends on the accuracy of the DSM, the aim of this paper is to introduced a method for true orthophoto generations by investigating accurate and efficient DSM through the use of LiDAR data. The objective of this research paper is to improve the quality of the output true orthophotos correspond to the building roof model that is generated by deriving heights from the DSM through interpolation technique.

1 INTRODUCTION

The spectrum of application areas dealing with orthophoto generation is increasing over the last few years so that the efficient generation of orthophoto is relevant task, both from practical and scientific point of views. Digital orthophoto production provided a larger flexibility taking mainly advantage of computing and digital image processing techniques (Mohamed ETTARID, Ali AIT M’HAND and Redouane ALOUI, Morocco, 2005). However, the orthophotos have some limitation on objects like buildings and bridges that they are distorted from their true location as those are not modeled in the DTM properly. Also, hidden effects caused by buildings and relief displacements in the orthophoto create inconsistent accuracy and scale, which especially shows when combined with vector-zed GIS data. The solution to overcome limitations of the orthophotos is the generation of accurate true orthopotos using DSM instead of DTM. There are several different techniques available to produce the true orthophoto based on aerial photographs and satellite images. In recent years, Airborne LiDAR is currently the most prominent technology to provide reliable and detailed 3D data on the earth surface and on the other hand, it helps to produce highly accurate and high resolution digital surface models (DSMs). Especially in highly urbanized areas, due to perspective occlusions, a photogrammetric DTM/DSM may produce a higher error rate than LiDAR (Brovelli & Cannata, 2004). Several researches have realized that the accuracy of true orthophoto depends on the accuracy of the DSM and also the DSM based only on the LiDAR data is not sufficient for the production of accurate true orthophoto especially in the urban areas. In this paper, a new approach for precise and efficient DSM generation form LiDAR data and vector based building outline data is presented to produce perfect digital true orthophoto.
This paper is organized as follows. The first section describes the introduction to the rationale of the research and it provides the background information on LIDAR system, orthphoto, true orthophoto etc. Section two outlines the data set used for the study. Section three presents the overall approach to generation of efficient true orthophotos. Results obtained with this method are shown and discussed in section four. The final section draws some conclusions and gives an outlook on future work.

2.1 Digital Orthophoto Imagery and Digital True Orthophoto Imagery

The original aerial photograph is not a true map as the elevation of the ground and the scale of the image has changed. The photo is orthorectified for relief displacement and eliminated the sensor tilt of raw aerial photo or imagery by using accurate representation of ground elevation data, and the product is a geometrically correct image of topography so that all features are correctly located as a map (Feng, 2000). (Fig 1)

Different rectification procedures have been traditionally used for orthophoto production (Konecny, 1979; Novak, 1992). In order to differentially rectified “conventional digital orthophoto”, DTM are used which, however, do not model objects like building, bridges. As a result, these artificial objects are displaced in the orthophoto from their true location and their original form may be distorted (Huep, 2006). True orthophoto is an orthophoto that all these defects are corrected including the leaning due to building heights and on which every object is placed at its correct geometric position by taking the DSM into account instead of DTM during the ortho rectification process (Nalani, 2007). However, the hidden area remains without image information in the true orthophoto due to the objects like building and bridges are moved back into their true location during ortho rectification process (Fig. 1.2). Generation of True-Orthophotos has to consider the orthogonal projection with a DSM, the detection of occluded areas and the filling up of the occluded areas by taking the missing image parts from overlapping orthophotos (J. Braun).

1.3 LiDAR Data

LiDAR, LADAR and LASER are acronyms, which stand for Light Detection and Ranging, LASER Detection and Ranging and Light Amplification by Stimulated Emission of Radiation respectively. LiDAR is the direct, optical analog to Radar system, which uses radio waves, but it incorporates laser pulses rather than sound waves. LiDAR systems determine distance by measuring the time delay between transmission and reflection of a pulse from the laser beam. (Lecture notes in Toni Schenk, 2004).
LiDAR laser pulses that transmitted towards the earth surface are reflected, absorbed and scattered before received by the receiver, which is based upon the surface characteristics. Most of the LiDAR scanners can record more than one signal for a single transmitted pulse. The individual reflections are referred as returns and designated as a first return, second return, etc. until the last return. LiDAR systems commonly record two echoes of the laser beam, the ‘first’ and the ‘last’ pulse. If the laser beam hits a solid surface such as terrain or building, first and last pulse will be represent as a same object point. While the laser beams hits a tree or a boundary of the building roofs, some part of the laser beam will be reflected from the top of the tree or roof, resulting registered first by the receiver called ‘First pulse’. The remainder will penetrate the vegetation and, thus, be entered further below, may be at the earth surface and hence generates the last returning pulse known as ‘Last pulse’ (Charaniya, 2004) (Fig 3). Additionally, a LiDAR system can provides intensity data (Fig 4) of the returned laser beam along with the run time of the laser beam, which can be used to determine, example the material type of the reflected object. The accuracy of LiDAR data depends on the accuracy of the GPS/IMU data, laser beam diameter and post processing procedures. The vertical accuracies of ±5cm can be achieved (Merrick, 2005) and it can also operated now a days at sampling frequencies of more than 50 KHz.

2. DATA PROPERTIES

Two primary data sets used in this research are LiDAR data and RGB digital images from Stuttgart area, Germany. The LiDAR data and images have been recorded by the TopScan GmbH. Two types of laser scanner data i.e. Range based first and last pulses are available. The recording has taken place on April 2006 by ALTM 2050 laser scanner with a measurement density of 4.8 per m² on the average and at around 1100 meters flight altitude. The aerial images have been recorded simultaneously using the Rollei AIC-modular-LS digital metric camera with a 20cm ground resolution.

3. THE TRUE ORTHOPHOTO PRODUCTION

3.1 Review of methodologies used to Generate true orthophotos

Several methods have been accomplished concerning the true orthophoto generation. All these methods are based on the same general concepts. Some of them which are related with this development are briefly reviewed in the following:

Amhr (1998) has described the method of true orthophoto production based on the merging of terrain models (DTMs) and buildings models (DBMs). In this method, the DTM and DBM has become
necessary in depth visibility analysis using DSM to overcome the case building occult each other. Amhr et al. (1998) had introduced Z-buffer method for true orthophoto generation that objects in lesser depth hide, those with greater depth with respect to the observer and this method was further investigated by Yougwel, Peng and Georgy (2003). The Z-buffer method resolved the ambiguity regarding which object point should be assigned to a certain image location by considering the distance between the perspective center and objects in question. But it had several limitations, which include the M-portion problem that is the false visibility associated with narrow vertical structures, and its sensitivity to the sampling interval of the DSM (Habib et al., 2007). Boldo (2003) has described the new approach for true orthophoto generation based on a segmented DSM. In this study, the enhance DSM acquired by correlation or LIDAR systems and the occulted areas were detected based on the tests of label values. The result of the segmentation is an image of labels that associate each pixel to a region number. Luigi Barazzetti et al. (2007) solved the true orthophoto generation problems based on LIDAR Dense Digital surface model (DDSM) acquired through LiDAR technology, coupled with a vector map describing the shape of buildings. The method was useful to create a high accuracy orthophoto in which every building is correctly rectified. However, the main problem was that the rectification of the gutter line of every building with a precision of the same order of the orthophoto’s geometric resolution.

3.2 Proposed Method of Efficient True Orthophoto Generation

Most of the researchers have realized that the DSM which is modeled only from the LIDAR data is not sufficient for efficient true orthophoto generation as the point cloud itself does not allow to detect the borders accurately. Furthermore, it is very difficult to detect the borders without gaps. In addition, the problems such as roof borders, ridges of buildings and relief displacement, etc are not represented correctly within the LIDAR DSM data. Therefore, in this approach, the DSM is modeled form LIDAR data and also vector data of building outlines and ridges. This process is carried out in four steps.

In the first step, DTM is created from the last pulse LIDAR measurements which are better representing the terrain surface than the first pulse LIDAR measurements as it penetrates the vegetation areas. The 3D points of buildings and remaining trees are removed from the LIDAR data and filled the footprints with a regular grid method. Secondary, building outlines and roof ridges are extracted from digital aerial images using segmentation method. In the next step, the DSM is modeled by superimposing the vector map of extracted building outlines on the LIDAR DTM. Then the rectification process of true orthophotos generation carried out based on re-projection method by taking the DSM into account. The height values of all pixels are interpolated using the DSM and all the 3D image coordinates of corresponding points are formed using perspective projection. The bilinear interpolation method is used for image re-sampling in this method as it is provided more smooth output image and also less un-sharp outlines when comparing with other methods such as nearest neighbour and cubic convolution. Then the interpolated grey levels from the input image are assigned to the output pixels of the orthophotos. In this case, 20cm ground resolution was selected for the output pixel size as it is identical to the input pixel size. These orthophotos might have gaps and missing information due to occulted areas in the images. Therefore, visibility test used to overcome the problem. All occulted areas are marked during the rectification process based on the results of the visibility test. However, the missing information is available on adjacent ortho-photographs. Therefore, it is necessary to merge different orthoimages.

Finally, the true orthophoto generation is done using mosaic process. In this process, all the occulted areas are filled with corresponding image information and merged the overlapping orthophotos to achieve true orthophotos.
4 RESULTS

LiDAR data and digital aerial photos form the input for the efficient true orthophoto generation with the methods that have been discussed in the previous section. This approach was tested with the data of the Stuttgart area in order to show the improvement in the true orthophoto quality obtained by adopting the proposed method. The first step in creating true orthophotos, is normal orthorectification of the imagery and in addition detection of the obscured areas in the images.

Fig. 6: (a) Ghost effect due to occulted areas (left), (b) Visibility checks and marked in red color (middle) and (c) True orthophoto (right)

The figure 7 shows that the different between true orthophoto produced from the proposed approach and also true orthophoto which is produced only using LiDAR DSM data (traditional method). Fig. 7 (a) also shows that true orthophoto produced using the LiDAR DSM only resulted in unshaped roof edges and ridges caused by blunders or gaps in the DSM. The proposed approach was able to overcome this unsharp building edges problem and also it shows that buildings have been correctly placed (Fig. 7. b) than the traditional method. The final result is shown in Fig. 8.a. Finally, for the enhanced 3D visualization, the generated true orthophoto is draped over the DSM (Fig. 8: b).

5 CONCLUSION AND OUTLOOKS

Digital true orthophotography has dramatically changed the nature of mapping. It has almost become an essential part of a GIS since it gives the user a spatial tool with excellent interpretative characteristics along with the geometric properties one expects from a good quality map. Therefore, the importance of true orthophotos is increasing. As shown, for effective true orthophotos it is essential to build up high quality DSM’s. The creation of DSM via LiDAR measurements alone is not sufficient for the generation of high quality true orthophotos especially in urban areas. Therefore, such kind of data must be expanded by introducing building borders and ridges to improve the quality
of the DSM. Therefore, this method can be used for the generation of accurate and more efficient true orthophotos. This gives the opportunity in future to generate more efficient true orthophotos which improve accuracy of DSM further.

Fig. 7: (a) True orthophoto of traditional method (left), (b) True orthophoto of proposed approach (right)

Fig. 8: (a) Full true orthophoto (left), (b) True orthophoto which is superimposed with DSM (right)

REFERENCES