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ENRICHMENT OF UAV PHOTOGRAMMETRIC POINT CLOUD TO ENHANCE DSM IN A DENSE URBAN REGION

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ABSTRACT:

Unmanned Arial Vehicle (UAV) have become very cost effective and time efficient technology for surveying, mapping and various other geospatial applications. UAV serves as a platform but the main dependency also lies on which type of the sensor is integrated on it. Optical photogrammetric surveys are more often conducted for generalized purposes and for its advantages. UAV photogrammetry have become very useful tool in creation of 3D city model or Digital twin model. But creating a Digital Surface Model (DSM) through photogrammetry is not that efficient when it comes to very dense urban regions. In this research, the quality of DSM, Noise in the Photogrammetric point cloud are studied, then an experimental approach is tried to enhance the DSM than that of DSM obtained from photogrammetric processing software. From the results, it is observed that the quality of DSM is enhanced in narrow streets/roads, near trees, regions between trees and buildings, regions near building and road, etc. This approach can be utilized for low-cost UAV photogrammetry for accurate 3D modelling of the narrow streets or roads are of critical importance

1. INTRODUCTION

Unmanned Aerial Vehicle (UAV) data products have become very cost effective and time efficient technology for surveying, mapping and various other geospatial applications. But at the same time it is also very necessary to statistically evaluate the accuracy these products generated from UAV. 3D modelling of the surface can done using two main techniques which are laser scanning and Close Range Photogrammetry (CRP). Laser scanning is very costly when compared to CRP, so photogrammetry is widely explored as an effective alternative technique.

Technique of 'Structure-from-Motion' (SfM) which uses high redundant bundle adjustment based on feature matching in multiple overlapping and offset images. Which is often used for photogrammetric process as a low cost and due to its user friendly approach (Westoby et al., 2012). SfM is based on concept of CRP which is Epipolar geometry. The principle of Epipolar Geometry is very clearly explained in (Kushwaha, 2018). SfM technique has become widely used process to obtain three-dimensional textured models. The quality of the 3D models also depend on the survey type and the processing methodologies applied on the datasets. So evaluating these 3D models obtained are also critically important. A research has been done to evaluate the accuracies of the control points obtained from the photogrammetric process and very high precision topographic survey which was done for the Church of San Miniato in Marcianella (Pisa, Italy). The UAV based photogrammetric data was also integrated with terrestrial photogrammetry for more dense point from both the terrestrial and top view (Caroti et al., 2015).

Multi image matching algorithm and computer vision plays a crucial role in extracting points for generation of Digital Surface Model (DSM) (Hu et al., 2016). It is also observed that there is also an error in vertical accuracy in the DSM and boundaries in orthophoto when the data acquisition is done in a regions where building's roof are very close to each other. Which either produces shadow or less overlap with high inclination (Liu et al., 2018).

The accuracy of measurements have improvised from metres to centimetres due to recent developments in accuracy of image orientation methods for oblique images which allow the images for high quality measurements (Ostrowski, 2016). An study has been carried out to test the accuracy of point cloud densities and the Digital Terrain Model (DTM) obtained by SfM and Multi-View Stereopsis (MVS) techniques (Agüera-Vega et al., 2020) and it was also observed that the point cloud generated were sparse in complex vegetation and the regions with homogeneous texture (Harwin & Lucieer, 2012).

For example, parameters tests like the chi-square test and student t-test can be used to evaluate the accuracy of ground control points obtained from UAV and topographic survey for DSM and orthophoto generated (Marques Junior et al., 2020). A research framework was presented to evaluate photogrammetric point cloud and DSM based on automatically extracted sample patches. At local and whole block level noise levels and Dense Image Matching (DIM) errors were also evaluated. Various factors which impact the DIM quality were also evaluated. In the research, it was also concluded that the overall quality on smooth ground regions improvised when oblique images were used along with nadir images for the processing (Zhang et al., 2018).

High topographic relief and complex geometry can contribute to an error in longitude, latitude and elevation differences. It has been observed that the accuracy is improvised by processing the

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images along with oblique images. But the angle of inclination and overlap also plays an role in accuracy and precision which is well documented and presented with different angle of camera inclination, overlap percentage of images (Nesbit & Hugenholtz, 2019) and changing flight plans (Chaudhry et al., 2020). Including the oblique images in SfM workflow also reduced the data gaps and systematic errors in the photogrammetric dense point cloud.

In addition, a study has been carried out to understand various camera calibration parameters present inside the UAV and how the accuracy is effected by installing an external Real Time Kinematic (RTK), complete workflow of photogrammetric process is also described (Jain, 2021). UAV images which are acquired at very low altitudes include illumination variance, Distortion and large rotation angles face multiple challenges of image orientation and processing. In a research, a robust approach is presented to process low altitude UAV images which involved a strip management method to automatically build a standardized regional aerial triangle network, a method to predict ground control points, a parallel inner orientation algorithm and an improved Scale Invariant Feature Transform (SIFT) method to produce large number of evenly distributed reliable tie points for bundle adjustment (Ai et al., 2015).

Dense urban areas are sometimes very complex regions for data acquisition as buildings are constructed in very compact space, building are at different elevations, the roof structure are different and presence trees in the study area. When the data acquisition is done with nadir camera orientation the points on the horizontal surfaces like roofs and roads are in more dense than the vertical surfaces like facades of the buildings (Kushwaha et al., 2019). In urban regions, point clouds play a crucial role in (Level of Detail) LOD2 modelling the buildings. A research has been focused on development of fully automatic and as a good alternative for the model driven method for generating building structure in urban regions. The algorithm is also efficient in noisy point clouds which is usually the case in Photogrammetric process. The algorithm also achieved consistent quality for the point clouds obtained from both either LiDAR or Photogrammetry (Xiong et al., 2014). A comparison between the point clouds obtained from LiDAR and Dense Image Matching in complex urban scenes is carried to understand their efficiency (Maltezos et al., 2016).

From the literature review and pre-analysis of the photogrammetric point cloud and DSM. Authors have observed that there is need for improvement in the dataset derivatives and scope of further enhancement. From the previous evaluation studies some of the critical issues observed by other researchers are also tried to answer through this research.

In this research, we would emphasis on the enrichment of point cloud and enhancement of DSM. During to UAV image acquisition procedure it is evident that there are some constraint for generating dense points in the regions between close buildings, regions between trees and buildings, regions between roads and buildings, which reduces the accuracy of the DSM. We are trying to improvise the dense point cloud in the regions where there are unavailability of points or very few points due to some limitations. Once the point cloud is enriched the DSM generated from this enriched point cloud would also be enhanced.

The Study area, dataset used, methodology followed and results are presented in the further sections in this paper.

2. STUDY AREA AND DATASET

For this research, a region with dense urban and narrow streets were needed where the proposed algorithm can be tested and implemented. For which Khanjarpur area which is located near Indian Institute of Technology – Roorkee, in Uttarakhand state of India was selected. The study area also consisted of few trees spread in the region. Which can also be a critical case to analyse the performance of methodology.

Figure 1. Shows the study area of Dense Urban which is located at Khanjarpur area in Uttarakhand State, India.

The data acquisition was done with the help of DJI Phantom 4 Pro (UAV) with an optical sensor mounted on it. The UAV flight was performed at an elevation of 150m above the ground height. The UAV images were processed in Agisoft Metashape professional software. The derivatives obtained from the process were further used for analysis.

3. RESEARCH OBJECTIVE

When DSM is generated from the photogrammetric process, it is not always feasible to generate a sufficient number of points between the tightly placed objects, for example, narrow streets/ roads between buildings or space between trees and building when they are close to each other in dense urban.. The currents situation is tried to visualize through a pictorial representation as shown in figure 2.

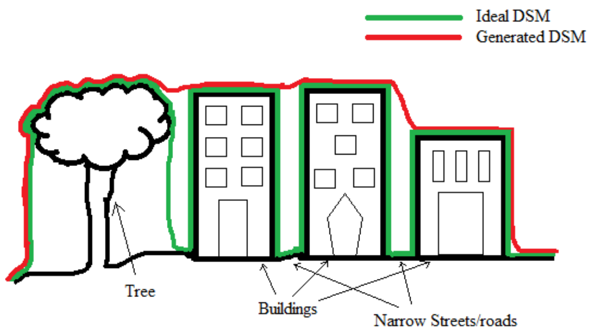


Figure 2. Pictorial representation of DSM generated from photogrammetric process (Red line) and the ideal DSM how the surface is present (Green line).

The research objective, is to enrich the generated photogrammetric point cloud and thus enhancing the accuracy of DSM in dense urban regions.

The idea is to enriched the photogrammetric point cloud by predicting the ground points in the regions of data unavailability and integrating it with the photogrammetric Point cloud, thus the DSM generated from this enriched point cloud would be much accurate than the DSM produced through the photogrammetric processing software's in case of dense urban regions which has narrow streets or roads.

4. RESEARCH METHODOLOGY

In this research, an approach is implemented to enhance the accuracy of DSM better than the DSM obtained from photogrammetric processing software by enhancing the photogrammetric point cloud derived (Figure 2). Very high resolution UAV images were acquired then they were processed in (Agisoft Metashape Professional) photogrammetric software to produce dense point cloud and DSM. Then the dense point cloud is classified into ground and non-ground points. Further, available ground points from the photogrammetric point cloud are used to interpolate ground points for the rest of the terrain (Figure 3).

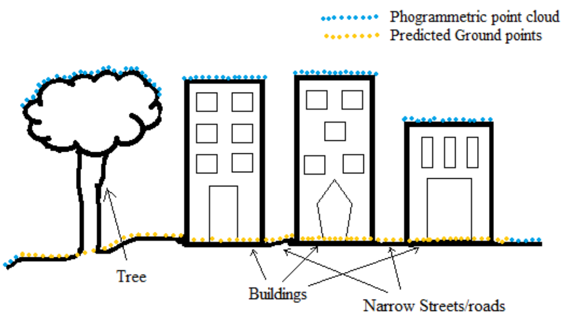


Figure 3. Pictorial representation of Photogrammetric point cloud (Blue points) and generated ground points (Yellow points).

Then the interpolated ground points and non-ground points are combined to generate a new point cloud. This new point cloud is used to generate a new DSM. Considering the new point cloud generated has non-ground points along with predicted ground points. Thus, ideally the DSM generated is much better in accuracy than the DSM produced through the photogrammetric processing software in regions of narrow streets or roads or tightly spaced regions. Then, the results obtained are analysed for the improvements in the DSM obtained. The research methodology followed in this research is pictorially represented in figure 4.

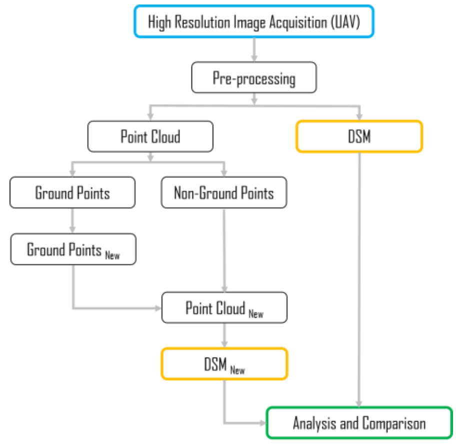
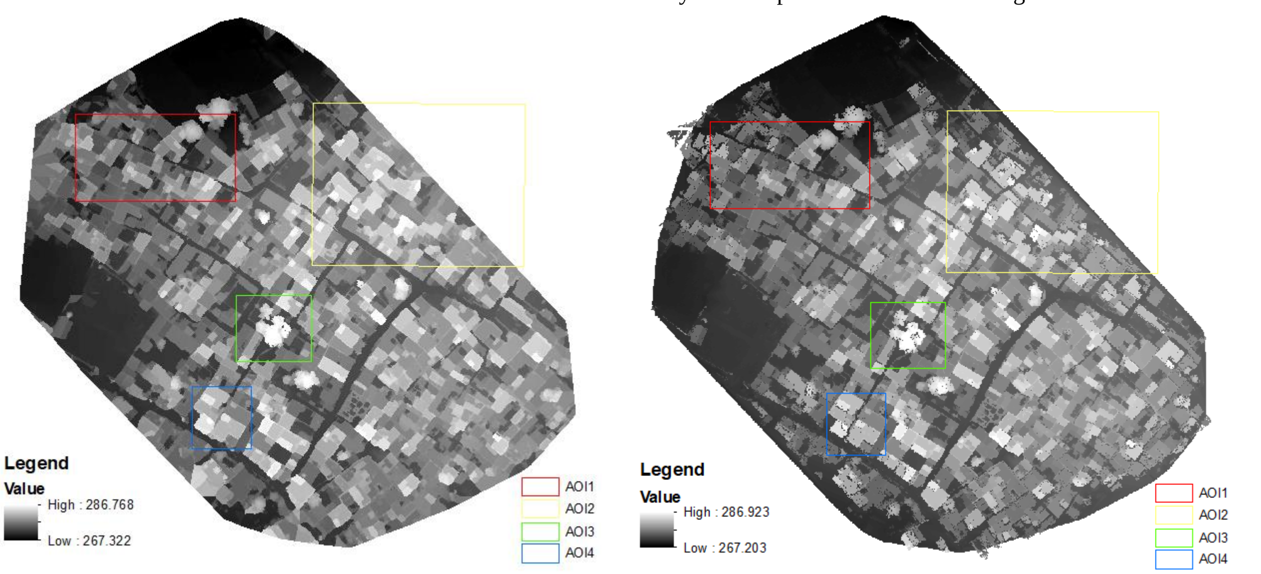


Figure 4. Research Methodology

5. RESULTS AND DISCUSSIONS

The new point cloud generated from the non-ground points together with interpolated ground points are used to generate an improved DSM. The DSM produced from the photogrammetric process using Agisoft Metashape Professional software and the enhanced DSM are shown in figure 5 below. Four Area of Interests (AOI) are also marked in different colours (AOI1 in red, AOI2 in yellow, AOI3 in green and AOI4 in blue) which are discussed in the further sections to further analyse the improvements in the DSM generated.



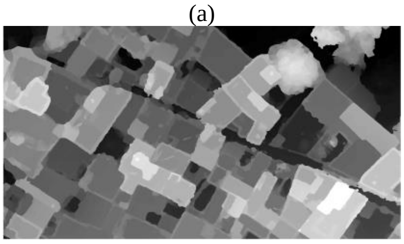
a) b)

Figure 5. Shows a) The DSM generated from the Agisoft Metashape Professional photogrammetric software, b) The enhanced DSM generated through the proposed methodology with Area of Interests marked in Red, Yellow, Green and Blue which are further used to analyse the improvements in DSM generated.

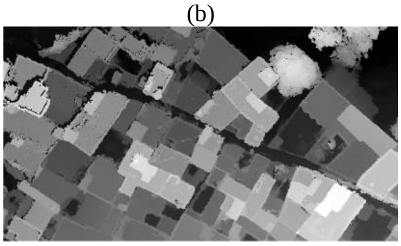
5.1 Case I – AOI1:

This AOI is chosen to analyse the improvement along the narrow streets as shown in figure 6a. There were very few points in the point cloud along the street as the buildings were very close to each other and the roof of the buildings were nearly touching each other in some places.

(a)



(b)



(c)

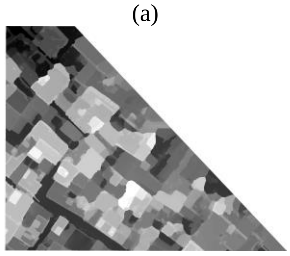
Figure 6. Shows a) Orthomosaic with blue polyline along which cross-section was taken, starting point is marked with 0, b) Software DSM, c) Enhanced DSM of AOI1.

From figure 6c, it is evident that the DSM is improved in the region of narrow street further, the vertical cross section of the elevation difference obtained in the narrow street is also shown in graph (figure 8).

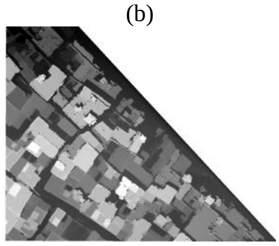
5.2 Case II – AOI2:

This AOI is chosen to analyse the improvements at the edges of the dataset. We can observe that at the edges of the datasets derived the information is not accurate and lot of information tends to omit.

(a)



(b)



(c)

Figure 7. Shows a) Orthomosaic with blue polyline along which cross-section was taken, starting point is marked with 0, b) Software DSM, c) Enhanced DSM of AOI2.

From figure 7c, it can be clearly seen that the DSM at the edges has been improvised from DSM shown in figure 7b. The vertical cross section of both the DSMs shown in figure 7b and 7c are shown in graph (figure 9).

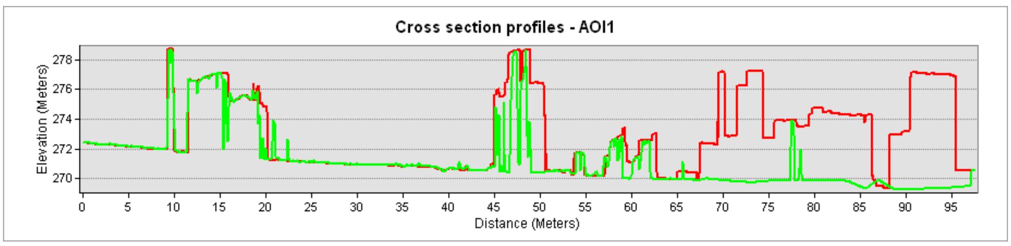


Figure 8. Vertical cross section of DSM obtained from photogrammetric software shown in Red and from Enhanced DSM obtained from research methodology shown in Green for the AOI1 region.

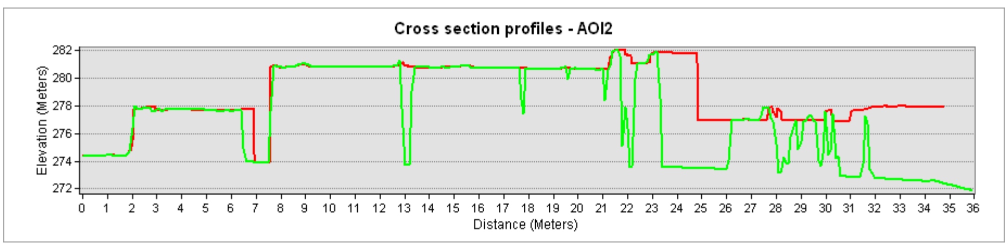


Figure 9. Vertical cross section of DSM obtained from photogrammetric software shown in Red and from Enhanced DSM obtained from research methodology shown in Green for the AOI2 region.

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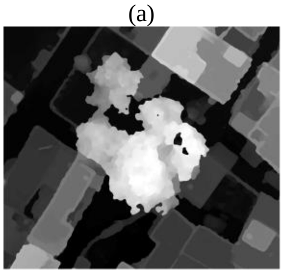
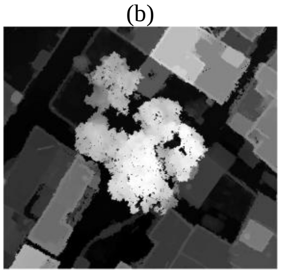
5.3 Case III – AOI3:

This AOI is chosen to analyse the improvements at the trees and regions between trees and buildings present in the the dataset.

(a)



(b)



(c)

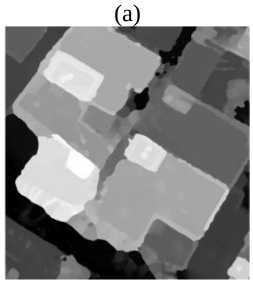
Figure 10. Shows a) Orthomosaic with blue polyline along which cross-section was taken, starting point is marked with 0, b) Software DSM, c) Enhanced DSM of AOI3.

From figure 10c, it can be seen that the DSM is improved in the regions where trees are present and the region between trees and buildings. Due to noise, it is difficult to generate points between trees and regions between trees and buildings. Which is improvised in figure 10c. Vertical cross section profiles are also shown in graph (figure 12).

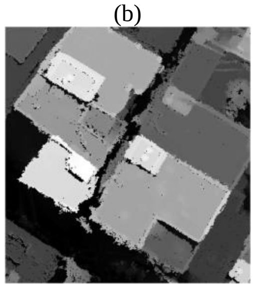
5.4 Case IV – AOI4:

This AOI is chosen to analyse the improvements at regions between the buildings and regions where buildings and roads are beside to each other in the dataset.

(a)



(b)



(c)

Figure 11. Shows a) Orthomosaic with blue polyline along which cross-section was taken, starting point is marked with 0, b) Software DSM, c) Enhanced DSM of AOI4.

From figure 11c, the region between buildings were initially not clear as the DSM was not accurate but after improvement region between buildings are clearly visible the vertical cross section profiles also shown in graph (figure 13).

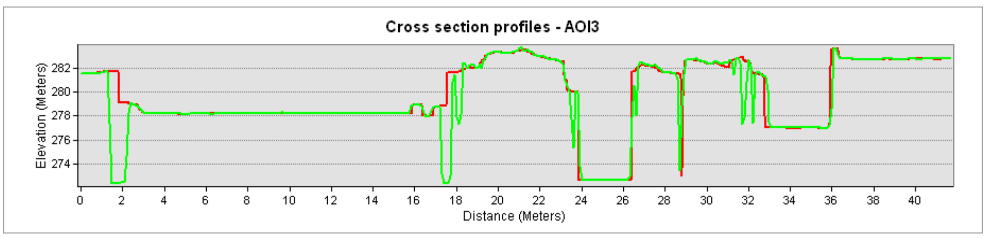


Figure 12. Vertical cross section of DSM obtained from photogrammetric software shown in Red and from Enhanced DSM obtained from research methodology shown in Green for the AOI3 region.

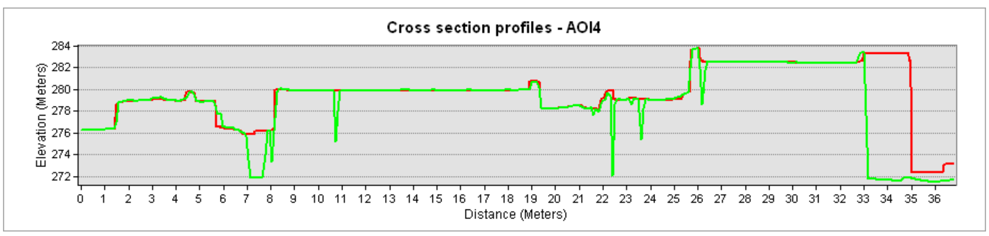


Figure 13. Vertical cross section of DSM obtained from photogrammetric software shown in Red and from Enhanced DSM obtained from research methodology shown in Green for the AOI4 region.

From the cross section profile graphs shown in figure 8,9,12 and 13. It can be clearly seen that there is an enhancement in the DSM generated from the regions in the narrow street, at the edges of the dataset, tree regions, space between buildings and regions between buildings and roads.

6. CONCLUSIONS AND FUTURE SCOPE

After analysing the results, it is observed that the quality of DSM is improvised drastically when compared with the DSM produced from photogrammetric processing software's in regions of narrow streets/roads and regions between trees and buildings. This approach can be utilised for low cost and accurate 3D modelling of the narrow streets or roads which are of critical importance. Which can also help in creating a digital twin model of the urban areas.

When the point cloud is generated from photogrammetric process, there are high possibility of getting noise at the edges of the buildings, between the buildings and space between trees and building. There can be improvements in the noise removal before enhancing the point cloud and DSM which will further improvise the accuracy of DSM produced.

Significant noise that occurs in photogrammetric process can also be reduced by using LiDAR technology but it increases too much cost.

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