Evaluating the quality of free and open source softwares for Digital Photogrammetric Applications

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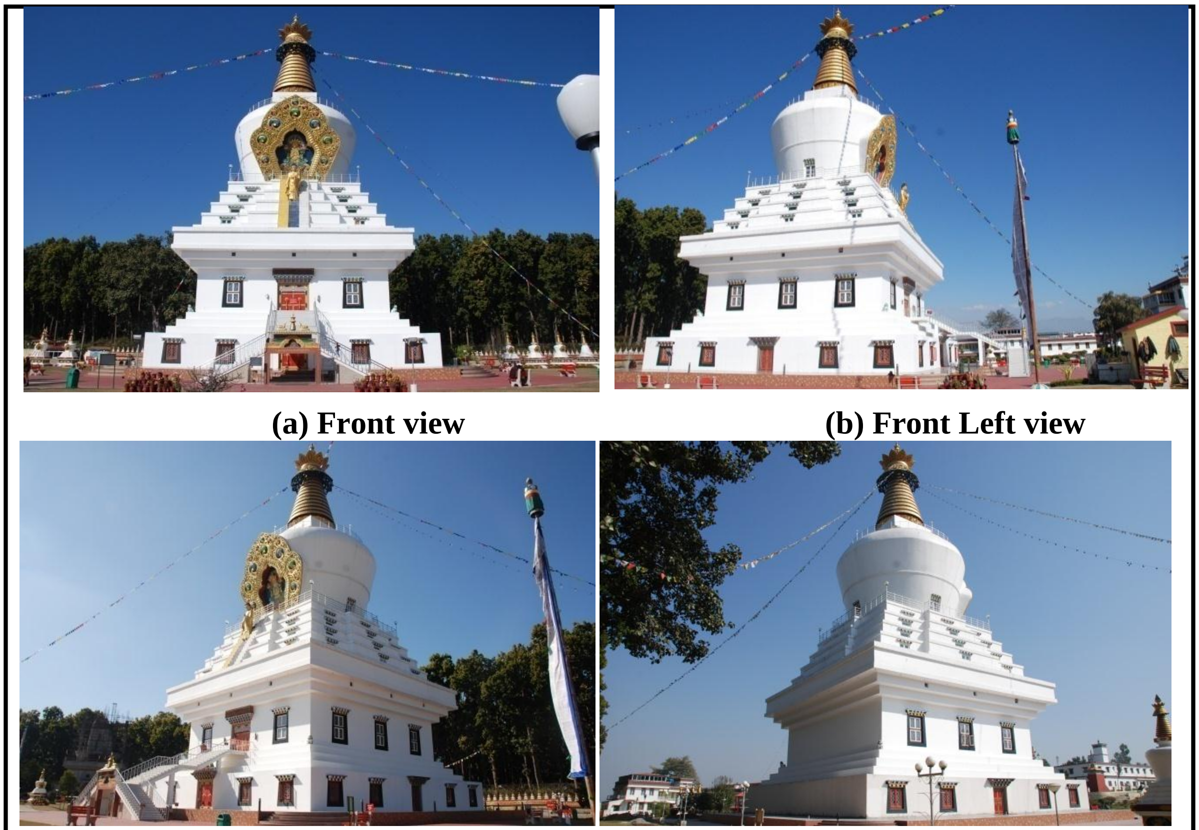
Introduction:

Recent years have seen a vast change in measurement technology. Advancement in computer vision, photogrammetry and digital technology has made it possible to analyze and examine the various complex structures such as items, locations or building in virtual 3D models. It is now possible to model a variety of structures in a more efficient way using Digital Close Range Photogrammetric technique [11]. Since, the revolution in digital technology has geared up production of low cost compact cameras and mobile phones with built-in digital cameras. Such products give us the opportunity to take photographs of any object instantly [1]. Now, this low-cost consumer grade camera generation makes it convenient to use it in the digital terrestrial photogrammetric field. As these are easy to handle and carried constantly, allow for capturing moments at any time. The current technological era also provides a wide range of freely accessible photogrammetric software for documenting the actual state of the object of real-world [2]. In these circumstances, one has to analytically study whether low-cost consumer grade cameras and free to use software are able to take place of DSLR and high cost professional photogrammetric software respectively in close range photogrammetric applications [12]. The study aims at evaluating the Photogrammetry based freeware with commercial software to evaluate whether open source softwares are feasible or not for 3D modeling and measurements. The study area chosen for first digital terrestrial photogrammetric application of this project is Buddha Temple located in Dehradun. Buddha Temple is a Tibetan Monestary, also called as Mindrolling Monastery. The Tibetan community of Dehradun builds the Buddha Temple as copy of Tibetan Monastery in 1965. It is located in Dehradun district in the state of Uttarakhand, India. Clement Town which is 7 km from clock tower in main city of Dehradun is the place where Mindrolling Monastery has been located. This is an important familiar sight of Dehradun. Mindrolling Monastery is famous for its astonishing architecture, attractive interiors, and eye-catching surroundings. The monastery complex spans an area of 8,100 m2 and is located at 30.27°N 78.07°E. The temple is 185 feet tall and 100 square feet in width. The Monastery is a dome shaped structure that is surrounded by a 2-acre landscape garden. The surrounding garden area is plain and has no structures that block the view of the temple. This clear view of the temple from all sides makes it easy for the temple to be modelled.

Dataset and Software used: For the study, digital terrestrial images and terrestrial laser scanner data of Mindrolling Monastery have been acquired using NIKON D-80 Digital SLR camera and Riegl VZ-400 terrestrial laser scanner respectively for 3D digital documentation of Monastery. The Tibetan community of Dehradun built this Temple as copy of Tibetan Monestary and is constructed in a Tibetan Buddhist architectural style. The latitude and longitude of the Monestary were also collected using a GPS device for geo-referencing purpose. For 3D point cloud generation Riscan Pro Laser Scanner, PhotoModeler Scanner [6] and Autodesk's 123D catch [7] softwares are used. The PhotoModeler Scanner and Riscan Pro are of commercial type software used for reconstructing and processing of point cloud data, while Autodesk 123D catch is a free to use web-based software used for reconstructing point cloud data. Also PhotoModeler Scanner and Autodesk's 123D catch are used for creating textured 3D model of Mindrolling Monastery. MeshLab [8] and Cloud Compare [9] are open source software used for visualizing point cloud data.



(a) Front view **(b) Front Left view**

(c) Front Right view **(d) Left Back View**

Figure1 : Terrestrial Photographs of Tibetan Buddhist Mindrolling Monastery acquired by Nikon D-80 SLR camera.

Methodology: For the present study, Range-based (Laser Scanner) and Image-based (photogrammetric) 3D modeling technique have been used for 3D modelling of the monument. In image-based 3D modeling two different photogrammetric softwares: PhotoModeler Scanner of commercial type and Autodesk 123D of web-based type have been used for 3D modeling purpose. Laser scanner data and terrestrial photographs that needs to be obtained will be acquired by Riegl VZ-400 terrestrial laser scanner and Nikon D-80 DSLR camera respectively. GPS points also need to be collected for obtaining better accuracy of the model. The planning and preparation step involves deciding which object needs to be captured, location for acquiring the data at test site and preparation of various devices and equipments which are required during data acquisition process. Riegl VZ-400 Laser Scanner, PhotoModeler Scanner and AutoDesk 123D catch used for generating point cloud data. For generating photorealistic 3D model, the PhotoModeler Scanner and free to use web based, AutoDesk 123D catch softwares are used. The point cloud generated using Riegl VZ-400 Laser Scanner, PhotoModeler Scanner and AutoDesk 123D catch are in local coordinates system. Point cloud data is georeferenced in GRASS 7 software for transforming point cloud data in local coordinates into global coordinates system. It is freely available GIS software. The analysis of point cloud data generated using Riegl VZ-400 Laser Scanner, PhotoModeler Scanner and AutoDesk 123D catch is done in two ways: Internal and External Accuracy Assessment of point cloud data [10]. The planarity of surfaces are assessed in internal accuracy assessment. This can be done by fitting a plane and then deviation of the point cloud is assessed [4]. In external accuracy assessment point cloud data of higher accuracy is used for comparing and assessing accuracy of the point cloud data. Thus, point cloud analysis will be used for comparing and analyzing commercial (PhotoModeler Scanner) and free to use web-based (Autodesk's 123D catch) close range photogrammetric software in comparison with terrestrial laser scanner (Riegl VZ-400) technique. In order to analyze the structure length accuracy of the model the comparison of ground measurements with model measurements (Riegl VZ-400 Laser Scanner point cloud data and PhotoModeler Scanner textured 3D model) is also done. Model measurements are those measurements which measured from the model [9] itself with the help of measuring tool whereas survey measurements are those which acquired from ground using measuring tape.

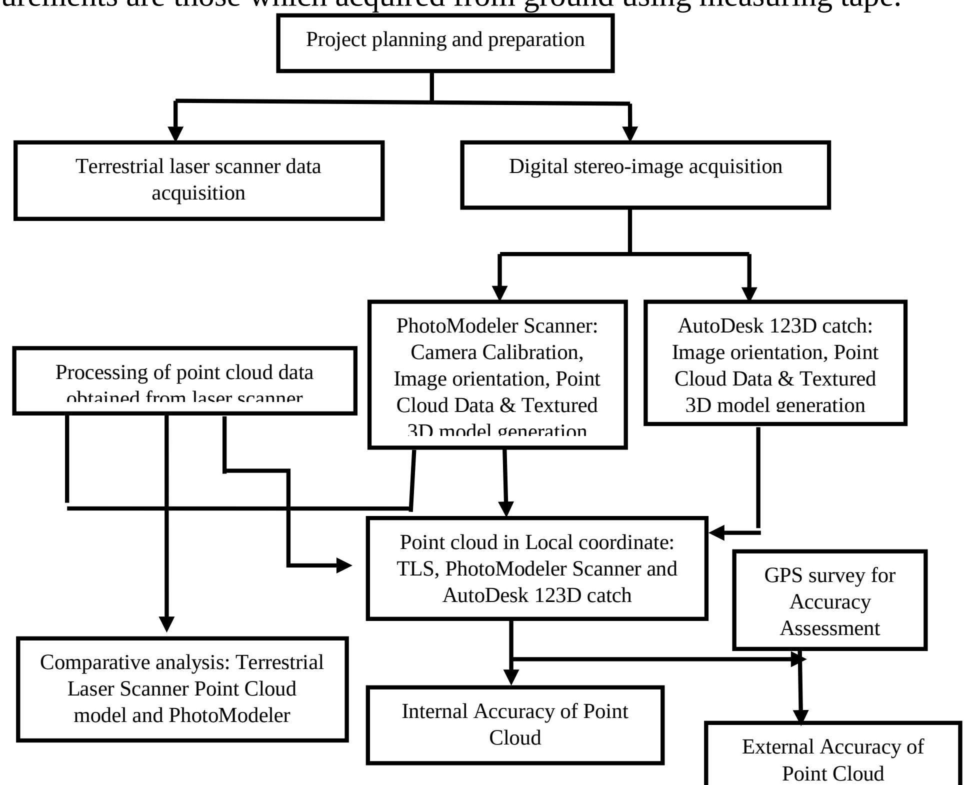


Figure2 : Brief Methodology

Results and Analysis:

Visual Analysis of Point Cloud

The point cloud reconstructed using terrestrial laser scanner is most visually impressive as compared to Autodesk 123D catch and PhotoModeler Scanner. In all three point cloud model the back portion of the dome of temple is absent. The reason behind this is due to the lack of space in back side the temple. The point cloud obtained using terrestrial laser scanner and Autodesk 123D catch are more evenly distributed as compared to PhotoModeler Scanner point cloud data. The terrestrial laser scanner point cloud data is densest as compared to PhotoModeler Scanner and Autodesk 123D point cloud data defining the structure of the temple in more detail.

The point density of PhotoModeler Scanner is more as compared to Autodesk 123D still some portion are missing and there are more holes in the point cloud in PhotoModeler Scanner. The features like wall, windows and other metallic features present at the top of the structure are documented well but the front lower portion is not modelled well in PhotoModeler Scanner and the points are not evenly distributed as compared Autodesk 123D.

The point density of Autodesk 123D catch is lowest as compared to terrestrial laser scanner and PhotoModeler Scanner but the points are evenly distributed and the overall features of the structure are documented well.

Figure 3: Point cloud a) TLS, b) Photomodellar, c) Autodesk 123D catch

Accuracy Analysis of Point Cloud Data

The quality of all the three point cloud can be assessed in two ways: Internal accuracy assessment and External accuracy assessment. In this section theoretical accuracy is also calculated and it is expected that final accuracy of point cloud data lie within this range[3].

Theoretical Accuracy of Point Cloud Data

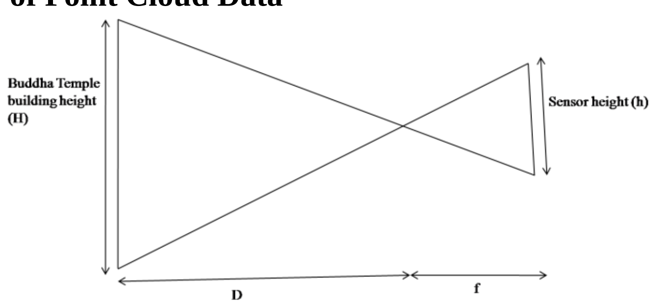


Figure 4: Camera geometry and Temple structure parameters.

Internal Accuracy Assessment of Point Cloud Data

In internal accuracy assessment the planarity of surfaces are assessed. For assessing internal accuracy of point cloud samples are selected, extracted and are fitted into a plane. Then, distances are calculated from point to plane. The similar features of the temple from the three point cloud data were subsetted using open source software Meshlab. Subsetted sample dataset 1, 2 and 3 have 2238, 259 and 424 points respectively. Figure 5 a), b), c) shows samples selected from the point cloud data taken from TLS, Autodesk 123D catch and PhotoModeler Scanner point model respectively. The samples were then saved in .txt format and then processed in MATLAB for analysis.

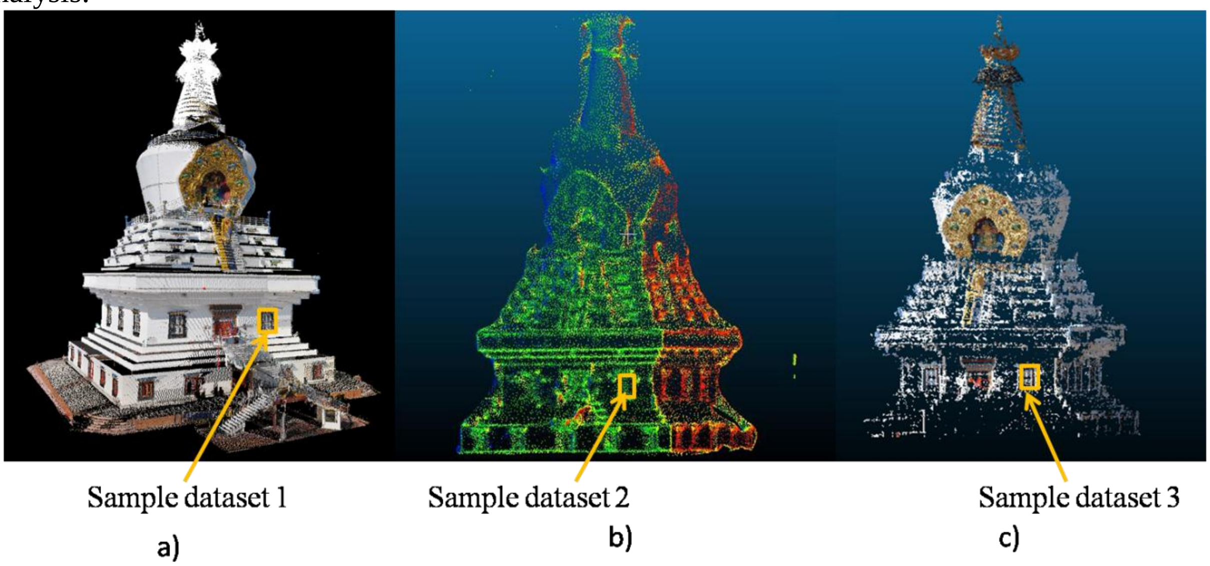
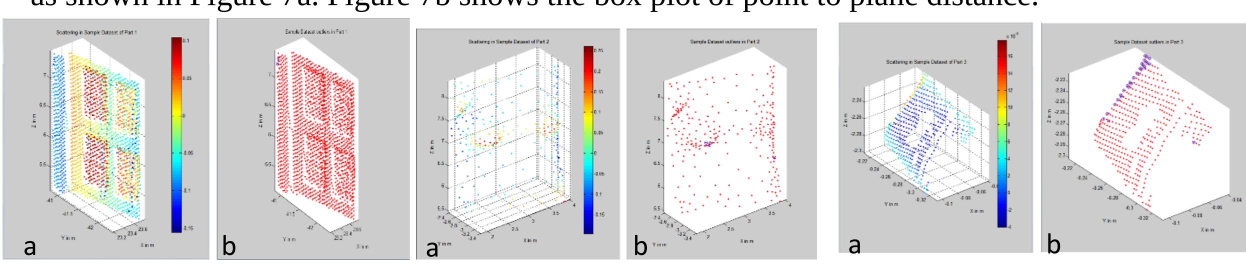


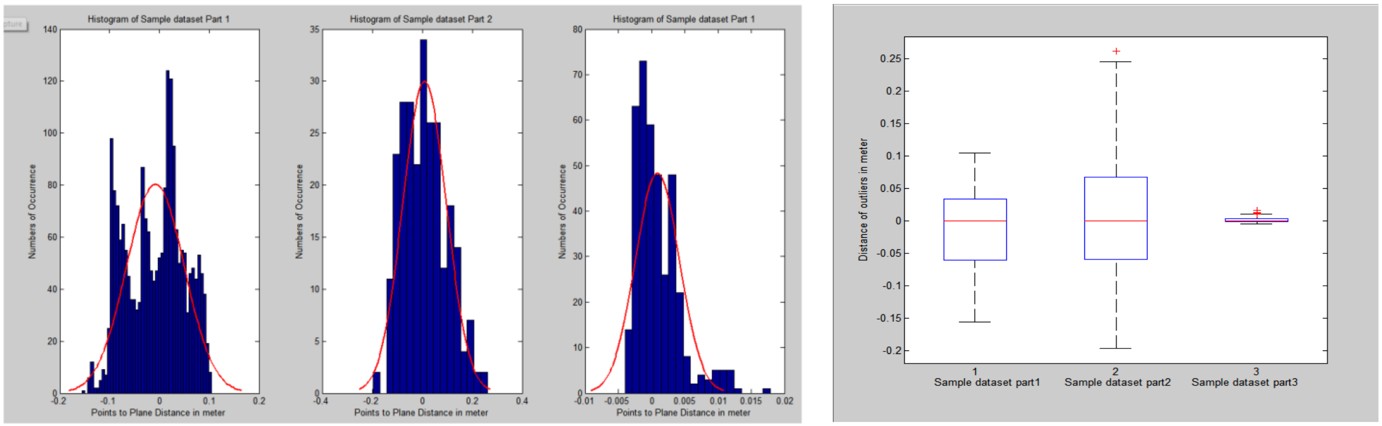
Figure 5: Samples selected from point cloud: a) TLS, b) 123D catch, c) PhotoModeler Scanner.

Figure 6 shows the scattering of points from the reference plane for TLS, 123D catch and PhotoModeler Scanner samples respectively. The Figure also represents the outliers in point to plane matching for the TLS, 123D catch and PhotoModeler Scanner samples respectively. The histogram of point to plane distance in meter was also plotted for sample 1, 2 and 3 respectively as shown in Figure 7a. Figure 7b shows the box plot of point to plane distance.



Sample 1 Sample 2 Sample 3

Figure 6: Sample dataset 1 (TLS), 2 (123D Catch) and 3 (PhotoModeler Scanner) (a) Scattering of samples (b) Outliers in point to plane matching.



a b

Figure 7 a: Histogram showing the Point to Plane Distance in sample dataset 1, 2 and 3 respectively; b: Box plot of sample dataset 1, 2 and 3

As per [5], in Figure 7 b, mid red lines shows median. At the top, blue line presents the upper quartile and shows that 25% of data above than this value. The bottom blue line represents the lower quartile and shows that 25% of data less than this value. The red plus symbol in the bottom and top shows the outliers which is less and more than 1.5 times of lower quartile and of upper quartile respectively. Top and Bottom black line shows greatest and least values excluding outliers respectively. The TLS plane has the small number of outliers, followed by Autodesk 123D catch plane whereas PhotoModeler Scanner have maximum number of outliers. This indicates that TLS plane is the most whereas PhotoModeler Scanner is least accurate in terms of internal accuracy assessment. By linking this analysis to the visual analysis as done in section 5.1.4, it is observe that points in TLS and Autodesk 123D catch point model are evenly distributed whereas in PhotoModeler Scanner points are irregularly distributed.

External Accuracy Assessment of Point Cloud Data

External Accuracy Assessment of point cloud is done by comparing the point cloud data of higher internal accuracy with that of lower internal accuracy of the same physical object of the real world[8]. Table 1 shows External Accuracy Assement for Autodesk 123D Point Cloud with TLS as reference. The External Accuracy Assement for PhotoModeler Scanner Point Cloud with TLS as reference is shown in Table 2.

Table 1: Error in Easting, Northing and Height for Autodesk 123D Point Cloud

S no.	**Error (TLS Measurements - Autodesk 123D Measurements) in meters**		
	Easting (E_{tls}- E_{123D})	**Northing (N_{tls}- N_{123D})**	**Height (H_{tls}- H_{123D})**
1.	0.15625	0.5	0.519165
2.	0.843751	0.5	0.7675169
3.	0.484375	0	0.264159
4.	0.625	0.5	0.057984
5.	1.328125	0.75	0.436767
6.	0.953125	0.75	0.161991
Mean Error	0.731771	0.416667	0.367931

Table 2: Error in Easting, Northing and Height for PhotoModeler Scanner Point Cloud

S no.	Error (TLS Measurements - PhotoModeler Scanner Measurements) in meters		
	Easting (E_{tls}- E_{PM})	Northing (N_{tls}- N_{PM})	Height (H_{tls}- H_{PM})
1.	0.703125	0	0.491639
2.	0.453125	0.5	0.820679
3.	0.71875	0	0.118651
4.	0.625	0.5	0.040650
5.	0.953125	1.75	0.530517
6.	0.859375	0.25	0.819156
Mean Error	0.71875	0.5	0.470216

Comparison of 3D Buddha Temple Model Measurements with Survey Measurements

Table 3 presents the Terrestrial Laser Scanner measurements, PhotoModeler Scanner Measurements and Survey Measurements for various parts of the temple. Total of nine dimensions were measured using a standard measurment tape. The mean error between Survey Measurements and Terrestrial Laser Scanner Measurements is 0.021 m (2.1 cm). The mean error between PhotoModeler Scanner Measurements and Survey Measurements is 0.038 m (3.8 cm). This shows that Terrestrial Laser Scanner is more accurate as compared to PhotoModeler Scanner.

The depth accuracy of 21 cm and parallel accuracy of 2 cm. The PhotoModeler Scanner model accuracy is 3.8 cm. This implies that theoretical accuracy is better than PhotoModeler Scanner model accuracy. The reason behind this inaccuracy may be the fact that for calculating theoretical accuracy the 35 m distance is used between the camera position and temple but in reality this distance is keep changing because of lack of space behind the temple and due to occlusions.

Table 3: Comparison of model measurements with survey measurements (in meters)

S no.	Survey Measurements (SM)	Terrestrial Laser Scanner Measurements (TLS)	PhotoModeler Scanner Measurements (PMS)	Error $SM - TLS$	Error $SM - PMS$
1.	27.4	27.42	27.44	0.02	0.04
2.	24.35	24.32	24.37	0.03	0.02
3.	3.02	3.05	2.99	0.03	0.03
4.	27.4	27.4	27.38	0	0.02
5.	24.35	24.32	24.27	0.03	0.08
6.	3.02	3.006	3.04	0.014	0.02
7.	27.4	27.42	27.38	0.02	0.02
8.	24.35	24.32	24.27	0.03	0.08
9.	3.02	3.01	2.98	0.01	0.04
Mean Error				**0.021**	**0.038**

Conclusion

The applications of digital terrestrial photogrammetry have largely enhanced because of the availability of freewares and low cost of digital cameras. The point cloud data and the generated phototextured 3D model yields an accurate geometry and measurements of parameters which are comparable to the real world scenario. The present work focuses on analysing the accuracy of 3D modeling using terrestrial photogrammetry. However, the accuracy factor depends on various parameters such as the resolution of the camera used for data acquisition, size of the object to be modelled etc.

We clearly find the effectiveness of both the techniques for cultural heritage modeling. From a quantitative point of view, laser scanning approach provided more accurate result than image-based modeling. Also, time required in laser scanning is less as compared to image-based modeling. In addition, image-based modeling constitutes a low-cost technique while laser scanning requires a large investment. In this research accuracy analysis of point cloud data is done in two ways: Internal Accuracy Assessment of point cloud and External Accuracy Assessment of point cloud. The Internal Accuracy analysis was done by assessing the planarity of the surfaces. The External Accuracy analysis was done by using ground truth data and highly dense point cloud. In this work Terrestrial Laser Scanner point cloud was used as a reference for assessing the accuracy of 123D catch (free to use web-based) and PhotoModeler Scanner (commercial) photogrammetric software. In Internal Accuracy Assessment of point cloud, we observed that terrestrial laser scanner model was most accurate followed by 123D catch whereas PhotoModeler Scanner was least. In External Accuracy Assessment, mean error for 123D catch were 0.73 m, 0.41 m and 0.36 m in easting, northing and height respectively where as mean error for PhotoModeler Scanner were 0.72 m, 0.5 m and 0.47 m in easting, northing and height respectively. It is also concluded from the above analysis that free to use web-based Autodesk 123D catch software is more accurate as compared to commercial photogrammetric software in terms of positional accuracy providing low cost alternative to expensive commercial photogrammetric softwares. But when accurate measurements are required from 3D models then commercial softwares are more accurate as compared to free to use software. Moreover, the texture quality of 123D software is not visually appealing as compared to PhotoModeler Scanner software.

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