Research article

Image based Virtual 3D Campus modeling by using CityEngine

Surendra Pal Singh[1*], Kamal Jain[1], V. Ravibabu Mandla[2]

[1]Department of Civil Engineering, Indian Institute of Technology-Roorkee, Roorkee, (PIN-247667) Uttrakhand, India

[2]School of Mechanical & Building Science, Vellore Institute of Technology (VIT) University, Vellore, (PIN-632014) Tamilnadu, India

E-mail *Corresponding author: surendra.geomatics@gmail.com

Abstract

At present scenario, various image based techniques are available for 3D modeling. Among of them, Photogrammetry and Laser scanning are the main geomatics techniques. Satellite photogrammetry and Aerial photogrammetry is not easy to use by every person, because the images are not easily available for everybody. Due to this reason, a new approach is possible to make virtual 3D model of any campus. In this research paper, a simple image based approach developed by using digital camera. This approach is very simple and very easy to use. This concept is based on only digital images. These digital images are easy to obtain by any handheld digital camera. In this study, we used the study area, campus of department of civil engineering, Indian Institute of Technology, Roorkee, India. This study is based on CityEngine software.
This paper will describe the introduction, methodology, advantages and limitations of this method.
On the basis of this study, we concluded that, image based method is very easy to create virtual 3D of any educational campus and this method is also very suitable for 3D modeling of an urban area. Cost and Time is main advantages of this method. In this paper, a simple and cheapest solution provided to create virtual 3D campus of any educational institute by using simple digital images. But this method also has some limitations. From this work, the advantages and limitations of this methodology also discussed. Thus it is a significance study and work for 3D modeling by using digital camera images. These 3D campus models can also be published on the website of that Institute or University. **Copyright © AJESTR, all rights reserved.**

Keywords: Procedural modeling, Image based modeling, Virtual visualization, Virtual 3D Model

1. Introduction

Virtual 3D modeling is a very important topic for researchers of geomatics. Many scientists are working in this direction. All over the world, so many educational institutes are available with its own campus. Campus is the land on which Institute; College or University buildings are situated. In the modern digital era, the demand of 3D campus is increasing. Virtual 3D model of campus gives a good and photo-realistic appearance [9]. Laser and Photos are two important data input to create 3D model. Laser input is very costly and can't afford by all institutes. Satellite photogrammetry and Aerial photogrammetry is not easy to use by every person, because the images are not easily available for everybody. [10].

The previous study [7],[9],[10], also shows that the digital terrestrial photos are good source to create cost effective virtual 3D campus of any institute. A good collection of literature can be found on Image based 3D modeling in Reference [5]. Close Range Photogrammetry (CRP) is also a good option to create virtual 3D campus modeling [2],[7],[10]. But in Close Range Photogrammetric work the main weakness are: Camera calibration, Experience photography, Roof texture, Complex mathematical modeling, and problem to find suitable position for photographs.

Anuar and Lawali [2], produced a virtual 3D campus model of University of Technology, Malaysia (UTM), by using photogrammetry. They use 3D digitization from stereo-photos.

C. Armenakis and G.Sohn, [4] also created iCampus, a 3D model for York University campus by using the images and aerial photos. The main aim of this project was to generate a virtual 3D model of York's university Campus. They use the airborne and terrestrial image with lidar data.

Singh et al., [6] design and developed a multi-camera setup. They also developed a method for multi camera calibration. It was a very good product for Digital Image data acquisition.

Shashi and Jain, [11], Singh et.al., [7], [10] also discussed about 3D building modeling from Close range Photogrammetry. They also discussed about the use of digital camera for 3D modeling.

Zulkepli Majid et.al., [19] , also created and discussed about 3D campus modeling by using Laser scanner.

Singh et.al., [8] also explained about virtual 3D city modeling techniques and Applications.

Singh *et.al.,* [9], also created an image based 3D model of campus by using SketchUp. It was also a very cheap and simple method to create 3D model of campus. But, it was also not advance 3D model and had some limitations.

Thus, a new method developed to create virtual 3D model of a campus by using CityEngine.

CityEngine software also creates new solutions for historic cities [1]. P. Chege, and R. Kamau, [12] discussed about 3D City models in ArcGIS and CityEngine.

B. Hohmann et.al., [3] explained the relation of GML shape grammar for semantically enriched 3D building models.

K. Petkov et.al., [13] explained about the fusion of GIS and procedural modeling for driving simulation in New York.

Zorko Sostaric, [20] explained the importance of Geodesign for 3D City by using CityEngine.

Procedural modeling discussed for cities by Yoav et.al., [17] and has various applications like for Digital cultural heritage [15], 3D GIS modeling [14] and texturing for 3D city models [16].

Because, photogrammetric method has a complex process and it requires experience. Due to these reasons, there is a need for new method to create virtual 3D campus model by using image based modeling. CityEngine is a good solution for these solutions. Thus this approach were tried to give a very low cost image based 3D solution for virtual 3D campus modeling by using CityEngine software.

CityEngine is a product from ESRI for 3D City modeling [21]. It works on Procedural modeling. Procedural modeling is the techniques of computer graphics which create 3D models and textures from some specifics sets of rules. In procedural modeling, algorithms are used to create a scene. The output is called as procedural content that can be used for computer games, film industry, and virtual tourism etc.

CityEngine creates a 3D city model of an area which can be publish directly on the internet for sharing the city model to other users. User can edit these models manually. Day by day, the demand of the realistic visualizations of a city is increasing, so the CityEngine is a useful tool to create a virtual 3D city model by using procedural modeling. It is also useful for virtual visualization of Archeological site of India.

In this work, the main focus was only on image based virtual 3D campus modeling and not using other features of this software. Image based modeling is easy than Grammar based or rule based 3D modeling. This 3D can be model published on the Internet for virtual visualization (18).

2. Study Area

Study area is Department of civil engineering, Indian Institute of Technology, Roorkee, (IIT-R), Uttarakhand, India. In Indian Institute of Technology, Roorkee, Civil Engineering department surrounded by Department of Architecture, Department of Water Resources Development and Management (WRD&M), and this Civil Engineering department has the following main sections and buildings: Geomatics section building, Geotechnical section building (having CAD Lab and Research scholar wing), Lecture hall building (having Newton room and Rayleigh rooms), Wind engineering section, O.P. Jain auditorium building, Transportation building, Main civil building, and Hydraulics building.
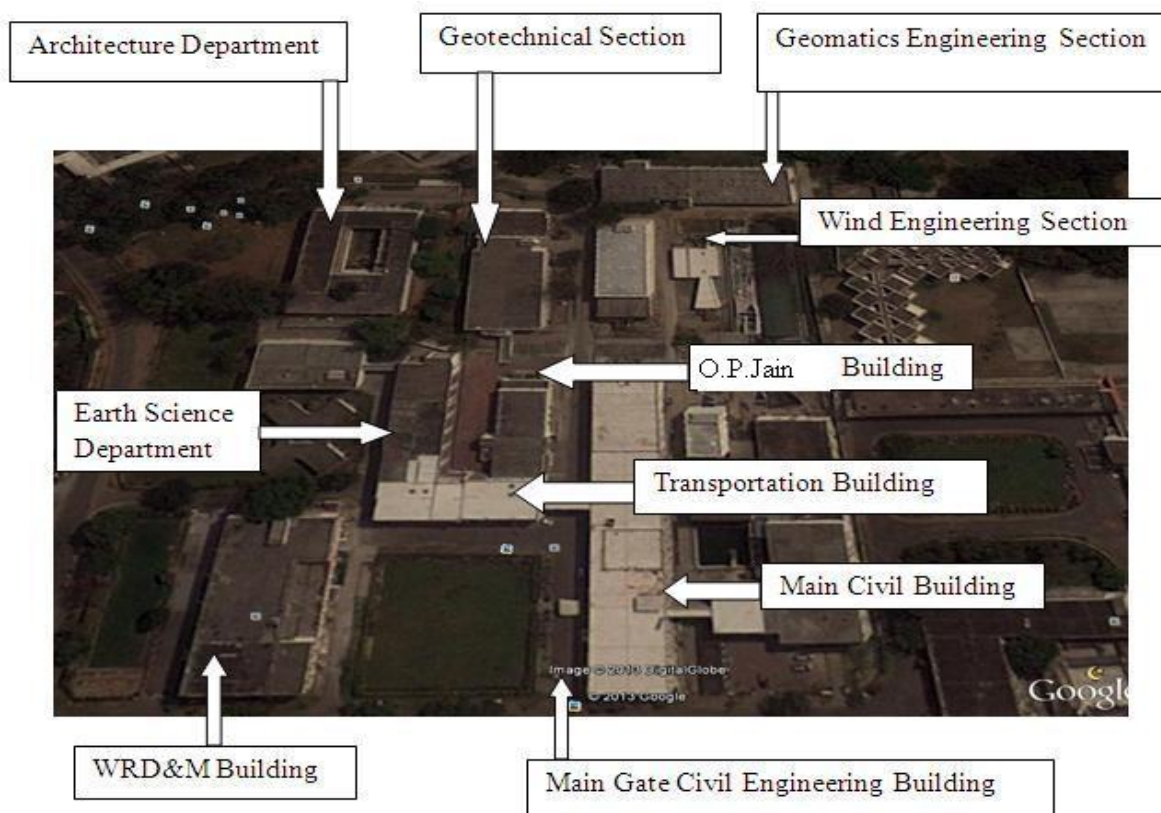

Figure 1. Department of Civil Engineering, IIT-Roorkee, India (Source: Google Earth, June2013) (Source: Ref. [10])

3. Methodology

CityEngine works mainly on Grammar based modeling, but I have work on a new approach, that is based only on simple image based modeling.

In this type of image based modeling, following are the main steps: Image acquisition from hand held digital camera, Shape file creation in CityEngine, Street network generation, Layer generation, Wireframe model generation, Building façade generation, Texturing of building facades, Manual editing and updating the building data, and final textured photorealistic 3-D building model generation.

In CityEngine environment, the shape file, street network, and other layers were created. Wireframe model generation, making building façade with texture, Manual editing, and updating the building data, are the main steps

3

for this process. At the end, the final textured 3D building model of department of civil engineering, IIT-Roorkee has been created. This 3D model can be exported to other formats for various applications.
These steps can be explained as:

1. **Image capturing by digital camera**: For the City Engine software, first the images of department of civil engineering, IIT-Roorkee were taken. Images ware taken with parallel photography, with some overlapping of area. Good quality of camera gives good texture during processing. For this work, the Sony DSC HX7V Digital Camera was used. (Figure 2.). The Photogrammetric property of this camera can be seen from Reference [10].

Figure 2. Sony DSC HX7V Camera used for Image Acquisition

2. **Shape file creation in CityEngine**: Now, shape file created in CityEngine software. Department of civil engineering, IIT-Roorkee, was chosen as the study area.

3. **Street Network generation:** In CityEngine software, Street network also created for department of civil engineering, IIT-Roorkee.

4. **Layer generation:** In this study, Building and Road layer has been created. Building and road is the main key feature for any area. Other layers may also create.

5. **Wireframe model generation:** The wireframe model of department of civil engineering was created . A 3D model without surfaces or textures is called as a Wireframe model. The wireframe model represents the building as a quantity of vertices and edges. This representation is true if anyone is interested in the general form of the building.
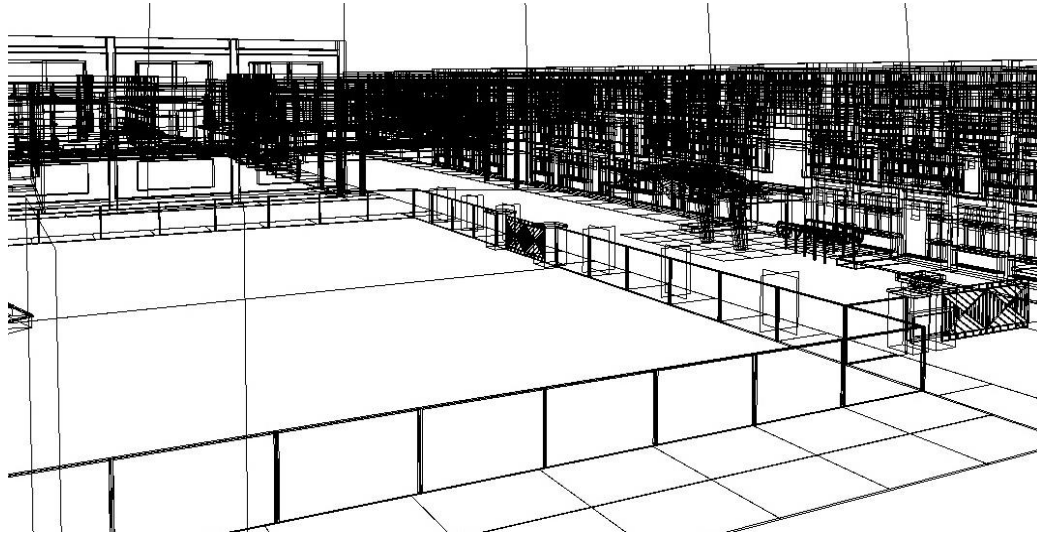
Figure 3. Wireframe model of Civil Engineering Department.

6. **Making of Building façade with Texture:**
   All building facade of department of civil engineering has been created with texture.   (See Figure 4)

Figure 4. Building façade with Texture

7. **Manual editing and updating the building and Road data:**
   In this step, all building and road of department of civil engineering has been edited manually.

8. Final Textured 3D Building model:

The various buildings of section in department of civil engineering, IIT-Roorkee was created. Main building of civil engineering department, Transportation section building, O.P. Jain auditorium building, Geotechnical section building, New lecture hall building, Wind engineering section building and Geomatics section building are the key component buildings of department of civil engineering. Fig. 6 is showing all buildings of civil engineering department.

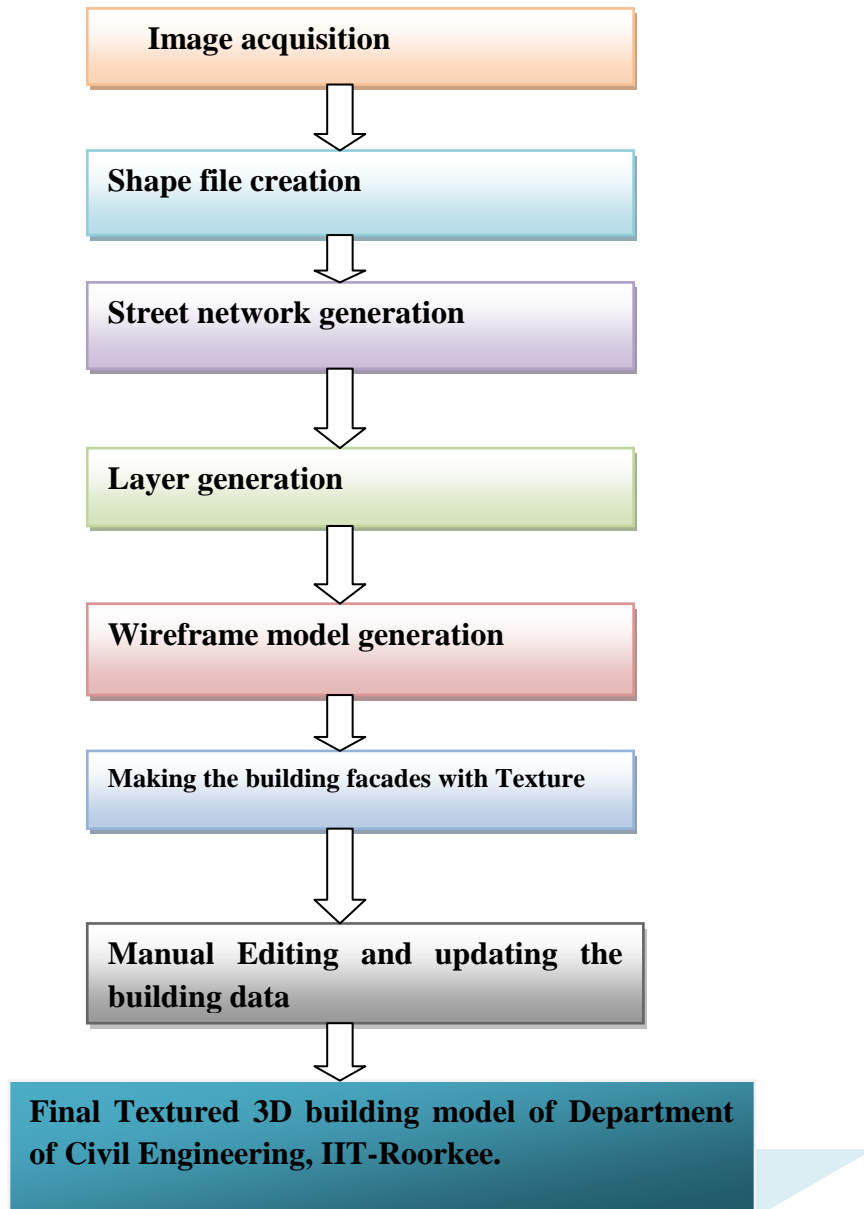The flow diagram of the methodology is showing as given below:

Figure 5. The flow diagram of the methodology

4. Software used

CityEngine software was used for this study. CityEngine was initially developed during PhD research work of Pascal Mueller, at ETH Zurich. He was also co-founder and CEO of Procedural Inc. This software is developed by formerly Procedural Inc. but now ESRI Research and Center Zurich and released in August 2008. It is commercial software for 3D urban modeling by digital images [21]. Anyone can create large scale 3D city models by using CityEngine software.

Main features of CityEngine:

Following are the main features for this City Engine;

- GIS/CAD Data Support
- Rule-based Modeling Framework
- Parametric modeling of 3D building and streets
- Interactive editing and city model updating
- Dynamic City Layouts
- Map-Controlled City Modeling
- Street Networks Patterns
- Facade Wizard
- Generic Reporting (BIM for Cities)
- Python interface
- Available for All Platforms
- **Industry-Standard 3D Formats:** CityEngine supports Collada, Autodesk FBX, 3DS, Wavefront OBJ, RenderMan RIB etc. which allow for flawless 3D data exchange.
- Batch Export of City model.
- Integration with ArcGIS

5. Results and Discussion

By this Image based study, a photorealistic virtual 3D model created for department of civil engineering, Indian Institute of Technology, Roorkee, (IIT-R), India. The Result is showing in Figure 6.
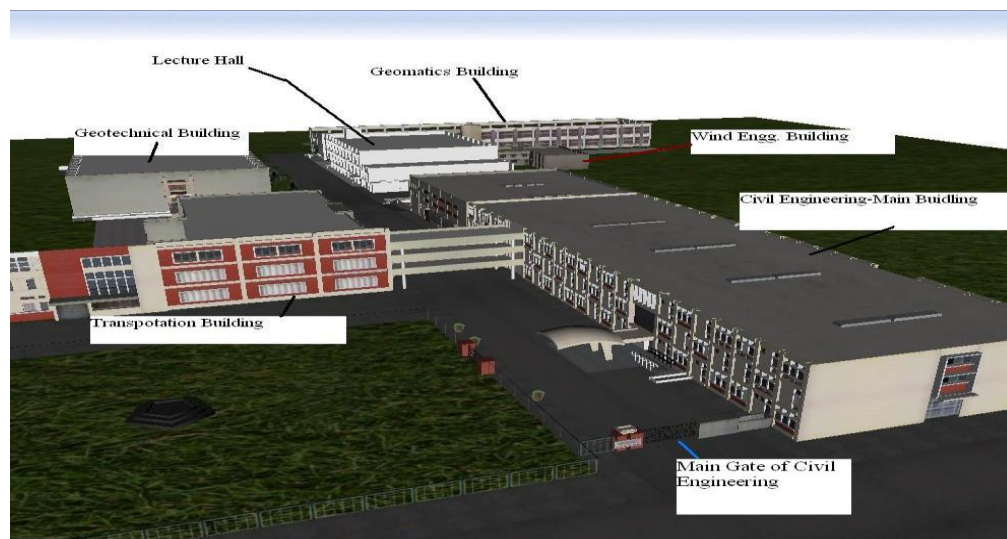

Figure 6. Textured 3D model of Civil Engineering Department, IIT-Roorkee.

A textured street view of department of civil engineering, IIT-Roorkee campus generated. It gives a realistic look for a model. It also covers more details of façade.
Texture quality depends on camera quality. High resolution of camera gives better textured model.
 This 3D model can be exported in the following format: KML, Collada, Autodesk FBX 2012, Autodesk 3Ds, Wavefront OBJ, ESRI file GDB, E-on software Vue, Reality server/Mental Ray, Pixar Renderman, RIB, Script based export (Python) and Massive prime.

This virtual 3-D building model is very useful and an important component to create a full Virtual 3-D City model. This method is also useful for Architecture and Urban Planning, Archeology, Virtual tourism, Building Information Modeling (BIM), Simulation, Restoration of Buildings etc.

Accuracy of Model:

In this method, the dimensions of road width, building height and building length also was measured. After this, these values have been added by Python script in 3D model. So accuracy of 3D model depends on accuracy of measurement. Anyone can set the unit of measurement in setup. Anyone can also scale the model with the help of measured dimension. For this 3D model, the accuracy of model is within acceptable limit.

6. Conclusion

CityEngine is very useful for 3D city modeling because in this software anyone can create and maintain 3D city model. Anyone can design and planning of new development (3D Zoning), anyone can also do typical urban analysis like shadow and visual impacts, Solar exposure etc. The 3D City model can be also published online, and it can also integrate with GIS.
So it concluded that, this Image based technique is very useful to create virtual 3D campus or virtual 3D city modeling, because in some area aerial images and satellite images are not easily available, but camera images are easily available. The cost and accuracy is also very good. By using this method, anyone can create virtual 3D model for various applications. By this study, it can be concluded: "Image based techniques and CityEngine software is a good and low cost tool to create photorealistic 3-D Model of a building". This image based 3D modeling work will be also useful for Civil Engineering and Architecture community.

Advantages and Limitations of this method are also discussed. Following are the main advantages and Limitation of this method;

6.1. Advantages:

The main Advantages of City Engine Product:
    City Engine is also a powerful tool to create virtual urban Environment. Following are the main advantages of City Engine software-
- Large area of a city can be generated from a smaller amount of rules.
- Large area of a city can be created with in less time.
- User may edit city model manually.
- The procedural modeling is focus on creating a model from a rule set, rather than editing the model via user input.
- City Engine gives a cost effective solution to create good Virtual site of an area.
- The city model can be exported to other software for further various applications.
- Import of city model from other formats is also possible.
- Updating of new buildings is also very easy to add in this model.
- Real time 3D City modeling is also possible.
- Layer wise information can be added very easily.
- Any digital camera can be used.
- Open Street Map can be directly open in CityEngine and generate the different layers like Road, Building, Parks etc.

6.2. Limitations:

Following are the main limitations for City Engine-

- Skilled person is very necessary to create the virtual 3D City model from City Engine.
- Understanding of procedural programming language is also not very easy. It requires lot of practices and experiences.
- Dimension of building cannot measure directly.
- Animation cannot make and play in CityEngine.
- Photographs should be in rectangular or parallel form for façade modeling.
- Snaping is useful for adding of two façade but   Snaping is not possible in CityEngine.
- Editing in photographs is very necessary for texturing of facade modeling.
- For each image, one façade is needed, so it increases the load of work in project.
- For adding the dimension in 3D model, the knowledge of Python programming is necessary.

Thus it concluded that this technique will be very useful to make virtual model of any Campus. This technique is very cost effective to create virtual 3D Campus model, compare to laser techniques. Based on this method, anyone can also make a virtual 3D city model. In absence of satellite images and aerial images, this method is most suitable for 3D modeling. Due to low cost, this method is also suitable then Laser scanning.

The purpose of this paper is to develop the concept for Image based 3D modeling for 3D city reconstruction. It will act as a bridge between Image based modeling and institutes, societies as well as people who take pictures not only for holiday memories but these photos can be useful for practical or scientific purposes.

Acknowledgment

References

[1] A New Dimension 3D GIS Brings the Virtual World to Life, June 2013, ESRI.

[2] Anuar Ahmad, Lawali Rabiu, "Generation of Three Dimensional Model of Building using Photogrammetric Technique", IEEE, 7th International Colloquium on Signal Processing and its Applications, 2011.

[3] B.Hohmann, S. Havemann, U. Krispel, and D. Fellner, "A GML shape grammar for semantically enriched 3D building models", Computers & Graphics, Elsevier, 34, Page. 322–334, 2010.

[4] C. Armenakis and Gunho Sohn, "i Campus : 3D Modeling of York University Campus", ASPRS 2009 Annual Conference, Baltimore, Maryland, March 9-13, 2009.

[5] Remondino, Fabio, and Sabry El-Hakim., "Image based 3D Modelling: A Review", The Photogrammetric Record, 21, 115, 269-291, 2006.

[6] Singh, Surendra Pal, Jain, Kamal, Mandla V. Ravibabu , "Design and Calibration of Multi Camera setup for 3D City modeling", International Journal of Engineering Research & Technology (IJERT),Vol. 2, Issue 5, May, 2013.

[7] Singh, Surendra Pal, Jain, Kamal, Mandla V. Ravibabu , "3-D Building Modeling from Close Range Photogrammetry", International conference in Geomatrix-12, CSRE, Indian Institute of Technology-Bombay, India, Feb 26-29, 2012.

[8] Singh, Surendra Pal, Jain, Kamal, Mandla V. Ravibabu , "Virtual 3D City modeling: Techniques and Applications", International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,Volume XL-2/W2, ISPRS 8th 3DGeoInfo Conference & WG II/2 Workshop, 27 – 29 November , Istanbul, Turkey, 2013.

[9] Singh, Surendra Pal, Jain, Kamal, Mandla V. Ravibabu , " Image Based 3D Modeling of Campus (Department of Civil Engineering, IIT Roorkee, Uttarakhand, India) by Using SketchUp", International Journal of Advanced Civil Engineering and Architecture Research, Volume 2, Issue 1, pp. 65-71, Article ID Tech-168, September, 2013.

[10] Singh, Surendra Pal, Jain, Kamal, Mandla V. Ravibabu, "Virtual 3D Campus Modeling by using Close Range Photogrammetry", American Journal of Civil Engineering and Architecture, Vol.1, No.6, 200-205,   December, 2013.

[11] Shashi, M. and Jain, Kamal, "Use of Photogrammetry in 3D Modeling and visualization of buildings", Asian Research Publishing Network (ARPN) - Journal of Engineering and Applied Sciences. Vol. 2, No. 2, April, 2007.

[12] Patrick Chege, and Raynah Kamau, "3D City models in ArcGIS and CityEngine", Experience Geopower in the east Africa, 3-5 Oct, ESRI, Eastern Africa, 2012.

[13] Kaloian Petkov, Arie Kaufman and Keeyoung Kim, "Fusion of GIS and Procedural Modeling for Driving Simulation in New York", The 10th International Conference & Expo on Emerging Technologies for a Smarter World, CEWIT2013, 21-22 Oct, New York, USA, 2013.

[14] Kristinn Nikulás Edvardsson, "3D GIS modeling using ESRI´s CityEngine: A case study from the University Jaume I in Castellón de la plana Spain", MSc (Geospatial Technologies) Thesis, University Jaume I in Castellón de la Plana Spain , March 2013.

[15] Simon Haegler, Pascal Müller and Luc Van Gool. "Procedural Modeling for Digital Cultural Heritage", EURASIP Journal on Image and Video Processing, 2009.

[16] Jürgen Bogdahn and Volker Coors, "Procedural Facade Textures for 3D City Models", 2009. http://geovisualisierung.net/geoviz_hamburg/papers/09_1_Bogdahn.pdf

[17] Yoav I H Parish and Pascal Müller, "Procedural Modeling of Cities", ACM SIGGRAPH, 12-17 August, Los Angeles, CA, USA, 2001.

[18] Zlatanova, S., Tempfli, K., "Modelling for 3D GIS:Spatial Analysis and Visualization Through The Web", IAPRS, Vol. XXXIII, Amsterdam, 2000.

[19] Zulkepli Majid, Halim Setan, Mohamad Ghazali Hashim, and Julian Goh, "3D Campus Modeling using Terrestrial Laser Scanning Technology –First Experience in Malaysia", 3D Geoinfo 2008, Seoul, KOREA, 13-14 November 2008.

[20] Zorko Sostaric, "Using CityEngine 2012 for Geodesign", Esri Asia Pacific User Conference, November 5-7, Auckland, New Zealand, 2012.

[21] CityEngine available online at (http://www.esri.com/software/cityengine)