

Application of 3D City Model and Method of Create of 3D Model- A Review Paper

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DOI: [10.36348/sjce.2022.v06i04.005](https://doi.org/10.36348/sjce.2022.v06i04.005)

| Received: 03.03.2022 | Accepted: 08.04.2022 | Published: 22.04.2022

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Abstract

In the last decades, 3D city models appear to have been predominantly used for visualisation; however, today they are being increasingly employed in a number of domains and for a large range of tasks beyond visualisation. In the past, the virtual 3D models are being built using primary materials, (e.g. wood), because of the flexibility and easy handling of this material, where the measurements are taken in traditional methods, so that the work is done in direct contact with the target [2]. However, with the advancement and development of techniques, the virtual 3D models are produced by computer-aided design and by using of auxiliary software's such as, AutoCAD but with manual measurements[8]. To overcome these difficulties, many techniques and remote sensing devices have been developed. These techniques are considered as the leaders in this respect and are commonly used in extracting 3D models nowadays such as photogrammetry and Light detection and ranging (Lidar). These techniques provide lots of information with high accuracy standards and reliability without direct contact with the real world (except for assessment and validation purposes). In this paper, we seek to understand and document the state of the art regarding the utilisation of 3D city models across multiple domains based on a comprehensive literature study including hundreds of research papers, technical reports and online resources.

Keywords: 3D city models, DTM, DEM, Routing.

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1. INTRODUCTION

A 3D city model is a representation of a part or all of the urban entity with a 3D geometry of common urban structures and objects with buildings that considered a notable feature [1,2]. An exemplary 3D city model is derived by different techniques, for example, photogrammetry, and laser scanning [3, 4]. It can be extracted from 2D images [5, 6], synthetic radar [9, 10], drawings and models of architectural [11, 12], and also procedural modeling [13, 14]. In recent decades, urban 3D city models seem to have been used mostly for visualization. However, with the development of technology, 3D city models have become important for many tasks beyond visualization nowadays, and are used in a large range of fields such as emergency response, shadow estimation, utility management, visibility analysis, indoor navigation and noise propagation, etc. [3, 15]. See Figure (1) for demonstration. This diversity and the growing number of applications make it difficult to trace the possibilities of using 3D city models. Efficient visualization of 3D

models in various levels of detail is one of the most important techniques to support any application.

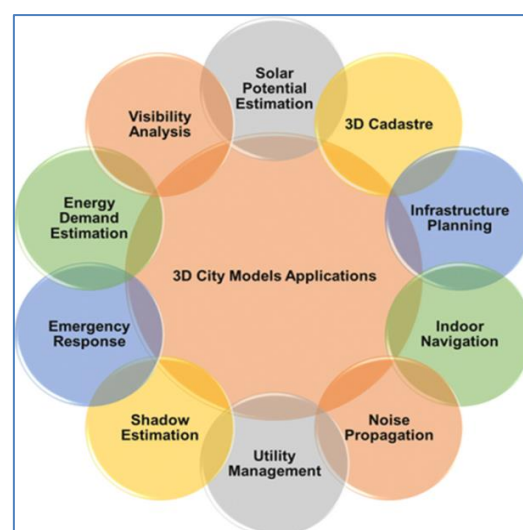


Fig-1: The various applications of 3D city models [11].

2- LITERATURE REVIEW

2.1. Applications of 3D City Models

3D city models have been widely utilized to support various applications such as planning of urban area, control of traffic, design of mobile telecommunication, etc. Many cities in the world are produced digitally and publish their official 3D model. For example, 3D Berlin is available online for any person since March 2009. It contains of 474,000 building, those are perfectly textured to represent reality, despite of the huge area of the city, which exceeds of 857 km². This 3D model can be visualized through Google Earth software [16]. The official 3D city model of Berlin is produced as a basis to gather, combine and publish existing geo-information and a framework for the city of Berlin for specialist and non-specialist to take part in planning and processes of making decisions. To deal with more details about 3D modeling, some related literature in the applications of 3D city modeling is listed and discussed in the following sections.

2.1.1. Planning of Urban Areas

Designers need the 3D city models to imagine the effect of the newly proposed planning on the city environment [17, 18]. Reference [19] used satellite images to develop a 3D-GIS application, an initial model to imagine the current situation of cities and to carry out simulations of the neighborhood development plan. In their application, high - resolution 3D city models are integrated with the 2D maps. However, reference [20], has been developed an application web-based interactive to support possible city planning in terms of information sharing, analysis, presentation, development and communication of opinions and suggestions for city planning operations. Some Parameters that relevant to city planning, for example, traffic system, electrical energy, distribution and management of water networks, green areas, etc. may integrated to increase the quality of both the planning process and results of planning. On the other hand, reference [21] use 3D model for managing street light through the identification of the effectiveness of these lighting on the streets with safety and security constraints.

2.1.2 Disaster Management

Organization of public safety, such as fire department, flooding center, or medical ambulance services needs for 3D city models to help them to locate the fire, flood, and accident sites [22]. Reference [23] implemented a system for flooding visualization based on 3D city models to explain the flood emergency. The estimating extent of flooding risk was traditional subjected in GIS, mostly with digital terrain models (DTM) [24, 25]. However, models of flood propagation and impact can be improved by water flow from water bodies or heavy rainfall using 3D city models [4]. References [26, 27] use 3D models to assess flood risk as shown in Figure (2) and detect the potential damage

on a small scale. This usage status is important for insurance (risk management), evacuation, and facility management.



Fig-2: 3D model to assess risk of flooding [27].

2.1.3 Estimation of Solar Irradiation

Estimating solar radiation falling on buildings is one of the most important applications that use and depend on 3D city model [28]. It is a mature subject in geographic information system where at first it was dependent on digital surface models [29]. Where 3D city models used to estimate how much solar radiation the building is exposed in order to determination the aptness of set up solar (photovoltaic) panels on this building [30, 31]. This is because it provides geometric information about the building, for example, the orientation, tilt and roof area, which are important information used to determine the best location of solar energy [32] as shown in Figure (3). The estimation of solar radiation on buildings is important, because it detects buildings, which rise in temperature during the summer [33, 34].

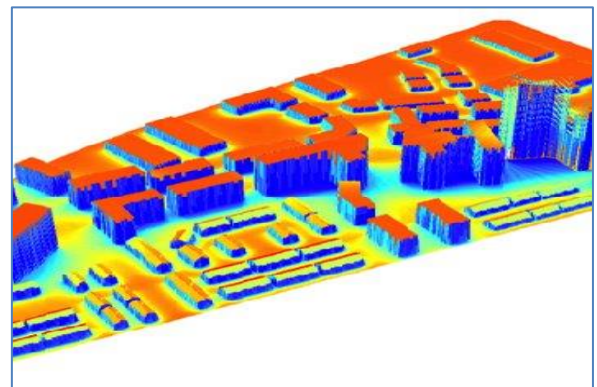


Fig-3: Location of solar energy based on 3D city modeling [34].

2.1.4 Visibility Analysis

3D city models cannot be dispensed for many applications that are specialized in the analysis of vision, for example, determining the line of sight between every two points in residential areas and to estimating the volume of seeing [35, 36]. See Figure (4) for demonstration. In addition, it can be used in estimating the visibility of a known location, and assessing the vision of well-known landmark from a

certain point [37, 38]. It also used for determining the better location for surveillance cameras [39, 40]. Moreover, it used in real estate evaluation in the urban areas based on the position of the building for other buildings, and also valuate the risk of snipers [41, 42].



Fig-4: The estimation of the line of sight between every two points from 3D city models [40].

2.1.5 Routing

Routing is a conventional 2D use application that is gaining more importance in 3D city models since when they used it for outdoor navigation [43], as shown in Figure (5). Reference [44] investigates 3D pedestrian navigation tool to enhance the available 2D data such as ramps and steps. This use case is considered as separate from the use case of visualization for navigation purposes. However, 3D models that contain indoor details can be used to find the optimal route and accessibility [45, 46]. This can be used with specific applications such as evacuation [47, 48], navigating large train stations [69], determining indoor routes for the disabled [49], and locating the shortest path to the nearest automated exterior defibrillator [50]. Recent research efforts comprise the integration of indoor and outdoor routing for indoor emergency response simplification [51].



Fig-5: 3D city models for outdoor navigation [51].

2.1.6 Spatial Analysis

Spatial analysis applications can be adopted by analyzing the 3D city models to serve several city matters. Reference [51] designed a closed-circuit television monitoring system based on 3D city models. However, [52] used 3D city models to plan telecommunication antenna networks as shown in Figure (6). The mercantile real estate community needs 3D city models to demonstrate their products, not only at the individual room level, but also in the suite,

building or surrounding area level. Whereas [53] used the 3D city model to analyze and visualize the noise level in North Rhine-Westphalia area in Germany. However, [54] made use of 3D city models for vehicle geo-localization use when the GPS information is not available or not accurate enough. On the other hand, [55] discussed the necessity of using 3D city buildings to act as electromagnetic models that define the size and shape of each 3D cell to form a mobile radio network.

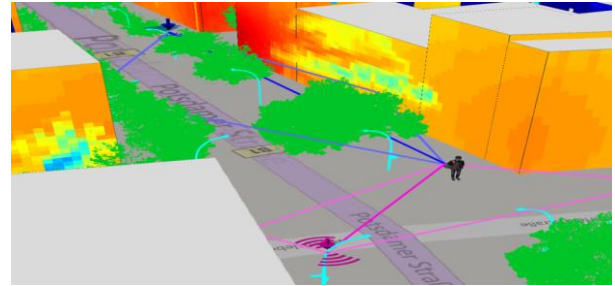


Fig-6: Planning of telecommunication antenna networks by 3D city models [55].

2.1.7 Other Applications of 3D City Model

1. Determination of shadows resulting from high buildings.
2. Determine the best location for triangulation points.
3. Classifying of building types.
4. Visualization for navigation.
5. Management of building Facilities.
6. Emergency response.
7. Detection of changes.

2.2. Methods of Creating 3D City Models

Many literatures have been presented in the last few years to create city models using various methods. Some researchers have studied the production of 3D city models based on processing type. Other researchers studied and discussed the creation of 3D city models based on data input technique. Hybrid methods those combine multi- techniques have been also presented and discussed. To understand these methods, a review from the literature was presented and discussed.

2.2.1 Processing Type Based Methods

Methods used to generate 3D models are usually distinctive based on different criteria. One of these criteria is the type of processing adopted to process the data and produce the model. They are usually classified into three main methods: Automatic, semi-automatic, and manual methods. Due to the huge number of urban objects in any city and the variety of shapes available, manual creation of a city model is a rather time-consuming and expensive procedure. In the manual method, the operator performs all tasks manually and using auxiliary programs such as AUT CAD software [56].

2.2.1.1 Semi-Automatic Methods

There are a few researches have worked on semi-automatic methods for city model reconstruction from aerial images [57, 58]. In the semi-automatic, the operator monitors the operations for extraction the features from the data. The operator may do some tasks manually, but these are implemented with the support of automatic techniques, and the results are still not satisfactory [59]. This is fundamentally due to the difficulty to recover 3D building structures from 2D images. Reference [60, 5] used and developed a semi-automatic approach for extraction 3D city model from high-resolution satellite imagery. They used Quick Bird data for the city of Istanbul using photogrammetric software platform. Whereas [61] use a semi-automatic approach to create a 3D city model by using data that extracted from the maps of cadastral and aerial images. They tested the derived model in a Roman site. The results were satisfactory and as shown in Figure (7) without texturing.



Fig-7: 3D City model without texture [61].

However, [62] use a semi-automatic approach for gaining 3D structured data from stereo aerial images in order to generate the model by using a digital photogrammetric workstation (Traster T10), and Micro station CAD package. The main steps in this work are data acquisition, data processing, superimposition, and visualization. On the other hand, [63] create the 3D city model by using a 2.5D maps (DEM). In order to compute the vertical distance for the building they used the scale of a map for the same area using GIS. They created 3D buildings and merged the solid buildings with DTM and the final result of the model is shown in Figure (8) below. This product is not for accurate applications.



Fig-8: A 3D city model [63]

2.2.1.2 Automatic Methods

The automatic acquisition of 3D models from sequences of image is one approach to the problem, which has been actively pursued by computer vision researchers in recent years. Fully automatic model recovery from images is usually based on low-level image features such as points and lines, which can be automatically detected fairly reliably [64, 65]. The automatic, procedures are done to create the full 3D model without any interaction from the worker [5, 6]. Reference, [66] explain a method to extract building features automatically from a data of laser scanning (3D point clouds). This is done by processing the point clouds with different segmentation algorithms, then extract from the segments several properties, such as (position, size, direction, etc.), and then determine building features such as walls, doors and windows, etc. To create a photo-realistic of 3D city model for a street-side as shown in Figure (9), [67] proposed an automatic approach by using images that captured along the streets. These images are captured by digital camera and based on several GCP's in the images used to create the model. The main defect of this method was due to the high amount of the high buildings available those limited the field of viewing of the ground-based camera.



Fig-9: 3D city model for a street-side [67].

Thereafter [68, 7] proposed a new method for automatically modeling the world by photo collections from internet as shown in Figure (10) below. They introduced a concept of a Photo-Tourism model. They proposed an approach to create 3D model of any building or site by using an unordered collection of photographs downloaded from the internet. In this project they used the concept of structure-from-motion and image-based rendering algorithms. They tested this approach for Google image search for "Notre Dame" (Paris), Mount Rushmore, a set of photos of Mount Rushmore National Monument, South Dakota, Trafalgar Square (London), Half dome in Yosemite National park, Trevi Fountain (Rome), Sphinx, (Giza), St. Basil's Cathedral (Moscow), Colosseum in Rome and also the Great Wall of China.

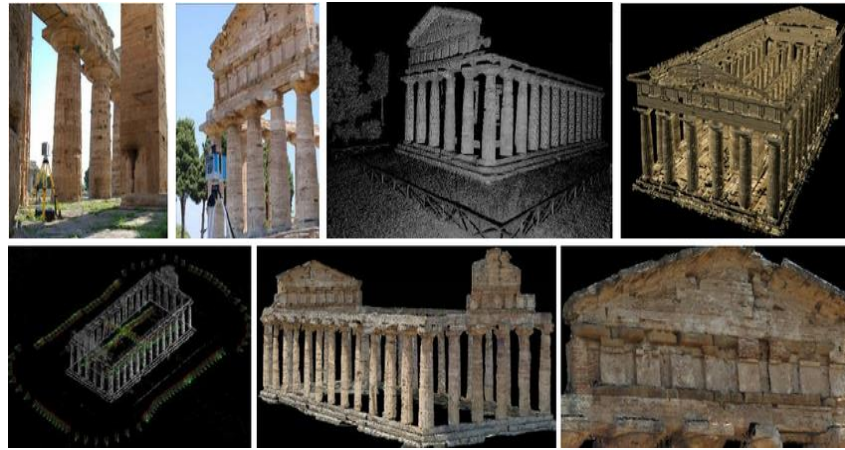


Fig-10: 3D model from a collection of photographs downloaded from the internet [68].

On the other hand, [69] developed a powerful system CyberCity Modeler (CC-Modeler). CyberCity-Modeler (CC-Modeler) is a methodology and software for the automatic generation of the topology of an unstructured 3D point cloud. It has been developed in order to generate structured data for city modeling from photogrammetrically measured points. It is specially designed for the dealing with 3D city data, and the integration of the vector data and raster images in terms of a hybrid GIS. While, [70] discuss a 3D object reconstruction by panoramic imagery from multiple-stations as shown in Figure (11). They described about image acquisition, panorama generation by frame imagery and by rotating line-scanner imagery, calibration, measurement of control points and tie points, panorama bundle adjustment to the final image compilation of 3D objects.



Fig-11: 3D Objects from panoramic imagery [70].

However, [71] recommend an automatic method and algorithm for 3D building reconstruction from 3D point clouds, delivered from laser scanning technique as shown in Figure (12). They used the well-known Hough transform for the extraction of planar faces from the irregularly distributed point clouds. They explored two different strategies to reconstruct building models from segmented ground points.

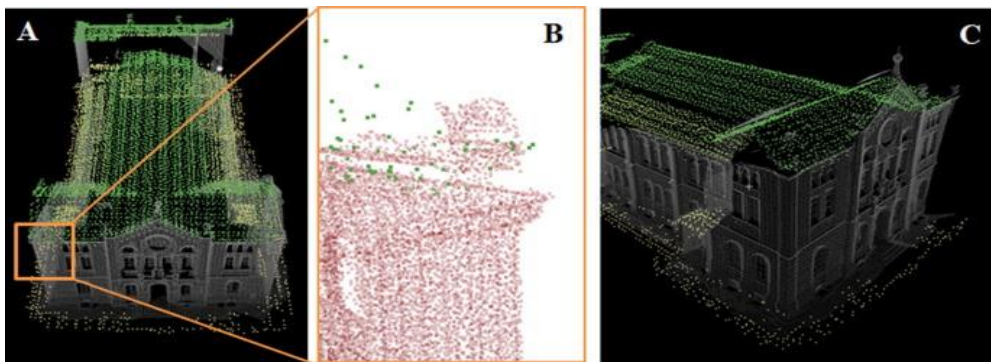


Fig-12: 3D building extracted from 3D laser point clouds [71][8].

On the other hand, the GIS can be successfully utilized to generate the 3D city model automatically. It is a computer-based tool for mapping and analyzing spatial data. The technology of GIS integrates operations of common database such as statistical analysis and query with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting

outcomes, and planning strategies. GIS is one of the most important new technologies, with the potential to revolutionize many aspects of society by increasing decision-making and problem-solving capacity. The maps making and geographic analysis are not new, but GIS makes these tasks faster and better than old manual methods. Therefore, GIS is used to apply the automatic process for the 3D modeling products such as Digital elevation models (DEM's). Further, reference [72] create a 3D city model for Yarmouk University in

Jordan and discuss the relationship between the 3D city model and GIS, through production of the GIS data-model with wanted relational database to view the flexible possibility and interactive visual analysis for constantly changing situations in the objects of the university. Further, they explain the GIS as a useful tool for spatial analysis of the third dimension. For assessing and comparison purposes, the researchers have applied the work on two distinct datasets. However, [73]

discuss the relationship between 3D GIS city modeling by GIS system and 3D city modeling by Google SketchUp software as shown in Figure (13). In this work the researcher explain the interoperable between two software and collecting 3D data with geoinformatics techniques to improve a 3D GIS database that includes buildings, terrain and other features which is relevant to 3D city modeling extraction process.

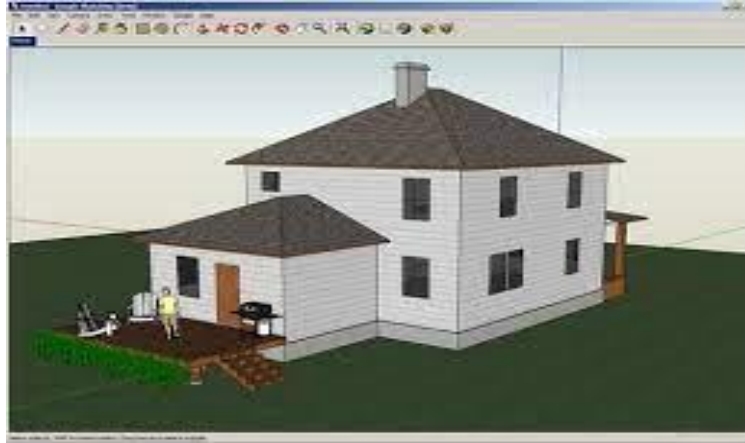


Fig-13: 3D model converted from Google SketchUp to GIS system [73].

Further, [74] use digital photogrammetry to generate the digital elevation model (DEM). He explained the purpose of DEM that enters into the design of a topographic mapping geologist and orthophoto. Further, [75] discuss the production of digital elevation model from 3D points that extract from aerial photos using different interpolation methods using Arc Map software. While, [76] represented the extraction of DEM from stereo satellite images (SPOT). On the other hand, [77] use automatic methods of interpolation to generate DEM from stereo pairs of satellite images (SPOT) and landsat images depending on the 3D ground coordinates, which is calculated using parallax equations. However, [79] discuss the process of generating DEM from different sources of data, such as Google Earth Pro, SRTM 30 and Topographical map. Reference, [89] generated the DEM based on the 3D coordinate that taken by Global Positioning System (GPS) also by using Geographic Information System (GIS). In contrary, [99] studied about the accuracy of DEM generated from contour maps using Arc Map software as shown in Figure (14). The researcher explained that the accuracy of the DEM is affected by the data source, amount, and quality of data. The analysis of the results was based on elevation differences, elevations percent, field measurements, and ground slopes. The researcher concluded from this study that this way of processing can produce a high quality of DEM, which is useful for geological applications.

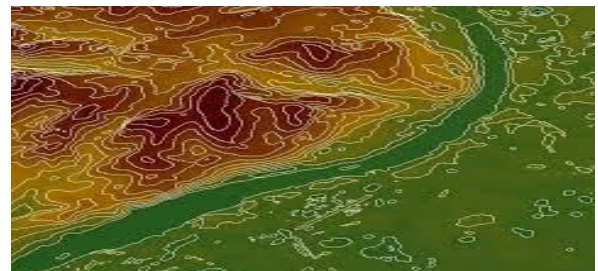


Fig-14: DEM generated from contour maps [99].

2.2.2 Technique Based Methods

Nowadays, the most common methods that used for acquisition of data to produce 3D city models are photogrammetry and laser scanning techniques. However, these techniques are also classified based on the input data type, which is mainly based on the sensor platform type. These platforms could be aerial terrestrial or space to capture the images for a certain application. With these techniques, the data are digital and usually accompanied by estimating the sensor orientations and locations. Although, 3D geometric information is not a direct production from these techniques, there are methods and procedures to be adopted to derive this information.

2.2.2.1 Photogrammetric Techniques

In order to collect data for 3D city model extraction, airborne, terrestrial, or space photogrammetry could be adopted. The aerial, terrestrial, and satellite images considered as a main source of raw data to extract the 3D point clouds from a stereo of images. Aerial photogrammetry is well suited for the economic acquisition of 3D city models, making

it possible to recover the structure as well as the dimensions. On the other hand, traditional photogrammetric measurement is mostly point based, which does not exploit the inherent structure of buildings, and thus cannot be economically optimal [66]. To compute the 3D point clouds, the pairs of stereo images are needed. The scale of the images depends on the accuracy that is required for the 3D model. However, in terrestrial photogrammetric technique, almost all current aerial systems can be applied to terrestrial images with some simple differences. Of course, also capture of data is feasible based on terrestrial images. The available commercially software tools allow for 3D measurement at high accuracy. Nevertheless, techniques of close range for architectural photogrammetry currently are too time consuming for an area to cover data collection. Airborne data are more or less equivalent to terrestrial images if geometric data capture is aspired, but the integration of terrestrial imagery is mandatory for applications like texture mapping [91]. On the other hand, space photogrammetry is considered the solution in case of vast areas. High-resolution satellite imagery is used, like the 1-meter panchromatic from Ikonos, and many others available nowadays with higher accuracies. The data capturing process is the same as with aerial images, but the accuracy is less because of variation the height of flying between the aerial and the space imageries. Further, DTM and Orthophoto can be derived automatically in space photogrammetry as shown in Figure (15) [87].

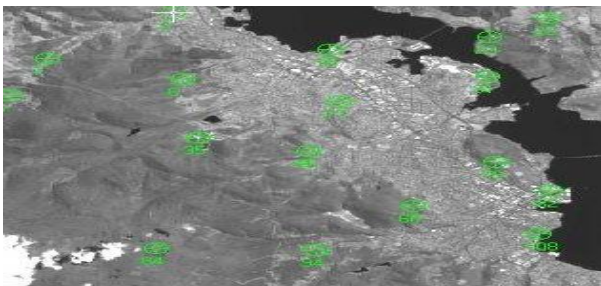


Fig-15: DTM derived from satellite imagery [87].

In this concern,[92] discuss the relationship between 3D city modeling and photogrammetry and generated 3D city model for Phoenix city, USA by using aerial images. They discussed the efficiency and effectiveness of the generated model through time and effort variables. However, [93] used close range photogrammetry (CRP) to create 3D model for any object and scene visualized within the study area. They found that CRP gives better solution and accuracy for 3D modeling because the CRP used to produce a virtual model for the small details as shown in Figure (16).

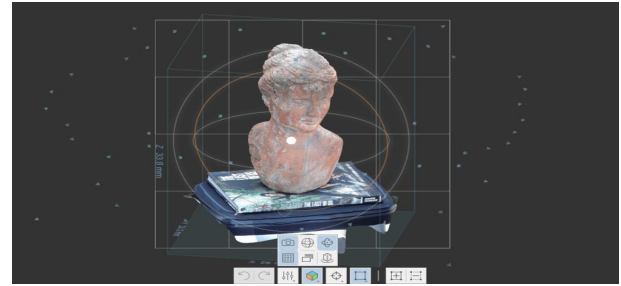


Fig-16: Virtual 3D model for a small object [92].

Further, [75] investigates a methodology to produce a textured 3D city model from sequences of images. The method is based on computer vision algorithms and CRP technique. In this method, the accuracy was low for metrological applications, but the texturing and visual quality were very cogent. On the other hand, [94] worked for 3D city model production from terrestrial images as shown in Figure (17). The benefit of this method was capturing a large number of images within a limited frame of time based on a certain setting. To correct their images poses, they used an algorithm that based on structure from motion (SFM) scenario.



Fig-17: 3D model production from terrestrial images [104].

However [5], discuss the process of creating the realistic 3D model using CRP technique. They use photomodeler software for camera calibration, image process, wireframe model and 3D solid structure and then insert the texture on the model from images. The results accuracy was mainly depending on the calibration of camera and camera resolution. On the other hand, [66] investigates a way to create a 3D city model by integrating CRP with aerial photogrammetry techniques as shown in Figure (18). In this way, they suggest that small buildings, windows, and doors cannot be extracted from aerial images, so CRP used to produce a virtual 3D model for the small details.



Fig-18: 3D city model integrating CRP with aerial photogrammetry techniques [65].

In contrary [90], use Ikonos satellite images to build a 3D city model. They used a pair of stereo images to create 3D buildings for the campus of the University of Melbourne. The results were with medium accuracy. However, [55] discuss a method to produce a 3D city model from single satellite image. They apply this method on a Quickbird image for Abu Dhabi area and the results were promising.

2.2.2.2 Laser Scanning Techniques

In airborne laser scanning, the scanner only scans a section perpendicular to the flight trajectory. The third dimension, which in the terrestrial application is caused by the motorized rotation of the instrument, is simply a product of the aircraft moving along its trajectory. In order to use airborne laser scanning for any practical applications, the position of the scanner at the time of every emitted pulse needs to be known. This

information is acquired by the combined use of GNSS (Global Navigation Satellite System) and an IMU (Inertial Measurement Unit) [5]. However, in terrestrial laser scanning, the instrument remains at a fixed location while the mirror deflects the emitted laser along the vertical axis. The azimuthal change in orientation is usually achieved by the use of a motor. Knowing the measured range of the laser as well as both the vertical and the azimuthal angles, it is possible to reconstruct a 3D scene from the data acquired. In this concern, [78] discuss the generated 3D city models by using point cloud data which acquiring from airborne laser scanning as shown in Figure (19) below. They suggest a comprehensive method for automated building extraction, regularization, and reconstruction from these point clouds. They based on accurate algorithms for 3D segmentation.

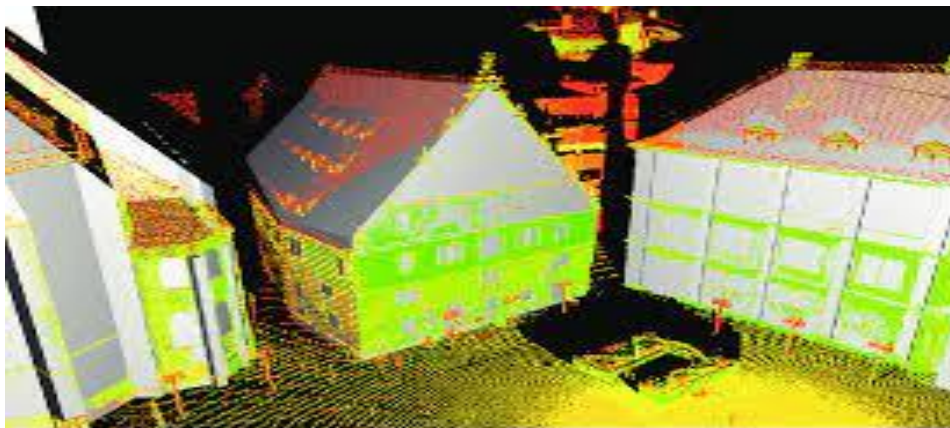


Fig-19: 3D city model by using point cloud data which acquiring from airborne laser scanning technique [78].

However, [79] developed an approach for accurate integration of terrestrial and aerial laser scanning data for realistic 3D city modeling extraction. For this approach, they used Leica HDS 3000 (TLS) and TopScan's OPTECH ALTM 1225 (AL) systems to generate the product. The terrestrial laser scanning (TLS) used to collect geometric detail about building facades and the aerial laser scanning (ALS) used to

collect geometric detail about the roofs of buildings. On the other hand, [64] tested the Three-Line Scanner system data to create Virtual 3D City model as shown in Figure (20). The TLS (Three-Line-Scanner) system is the system of aerial camera that developed by STARLABO, in the year 2000 in Tokyo (Japan). They produced high-resolution photo textured models of Yokohama with CyberCity Modeler software.



Fig-20: 3D textured model of city [64].

2.2.2.3 Hybrid Techniques

The techniques that combine both sources of data (photogrammetry and laser scanning) or any other source of data in order to generate the model is called hybrid as it comes from data delivered from different multiple sensors. In this regard, reference, [90] investigates the approach and algorithms to automatically generate a 3D city model from laser

scanning and image data. They implemented automatic registration routine for 3D point cloud acquisition by applying automatic selection for the targets those are used for geo-referencing and generated surface model following automatic plane detection, and texture mapping. They achieved an approach that is useful to generate the accurate 3D city model from digital images and point clouds as shown in Figure (21) below.



Fig-21: The textured point cloud model with laser and images.

Further, [44] suggested an approach to generate a pragmatic 3D city model by integrating airborne imagery and Lidar data. They used orthophotos and DSM to make the 3D model more realistic by using Arc Scene GIS software and later added 3D symbols to the generated model. This work was tested for the campus of the University of Calgary and show efficiency. Also, [42] evaluated a method for joint collection of point cloud that acquired by airborne laser scanner and DSM that generated by technique of photogrammetry for 3D city model reconstruction. However, [43] discuss the differences between point clouds generated from images and those generated from laser scanning. They concluded that the accuracy of

photogrammetric result is good if compared to laser. They also found that the density of surface points that generate from images is very high. However, the photogrammetric technique needs more time for the process if compared to the laser scanning ones. Further, [44] developed an approach to generate 3D city model by matching aerial laser and terrestrial laser techniques with historical maps as shown in Figure (24). The researchers used Optech ALTM 3033 system for laser surveying. They also have acquired high-resolution images for the same area using Nikon D100 to generate the facades. They generated the 3D buildings with the help of TerraScan software.



Fig-24: 3D city model by matching aerial laser and terrestrial laser.

CONCLUSION

Comparative statements of this research paper can be summarized in the following words: In the starting of computer era, the quality of 3D City model was not effective, but in present scenario, due to the advance techniques and algorithms, the real time web-based photo-textured, scalable and accurate 3D City modeling is possible. Accuracy of 3D City model is depends on the scale of aerial images and is normally about 1:5000 with a forward and a side overlaps of 30 and 60 percent respectively. Using this data, many building details can be measured from the aerial images and the measurement error is maximal 0.2 meter in height. The Hybrid methods are also gives good results. The combination of terrestrial close range images and aerial images are give a good solution, But in some country, the Arial flight is not allowed due to security purpose. The combination of terrestrial laser and Arial laser (ALTM) is also produced 3D City model of large area with in less time. The fusion of Laser and Photographs is also gives the best result for 3D City modeling. Depends upon user requirements and available resources, any method can be used. Very High Resolution satellite images will also be very useful for the 3D City modeling. Now a days, current trends is going for Laser scanning techniques, but this techniques also have some drawbacks like cost of equipments, point cloud data size, editing. Storing and management is also an important issue. In some country like India, where aerial flight is restricted for mapping and modeling purpose. So in these cases: Close range photogrammetric method is most effective solution to create 3D City model. It gives better result and good accuracy. Conclusion of this research paper is that, So many researchers are working for 3D City modeling, some are working for Techniques and some of them are working for Applications of 3D City modeling. Research is going on continuously to achieve more and more accuracy in less time with low cost of project, so these 3D City model can be used for various engineering and non-engineering purposes.

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