


# Integrating Highly Spatial Satellite Image for 3D Buildings Modelling Using Geospatial Algorithms and Architecture Environment

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## Abstract

The growing demand for current and precise geographic information that pertains to urban areas has given rise to a significant interest in digital surface models that exhibit a high level of detail. Traditional methods for creating digital surface models are insufficient to reflect the details of earth's features. These models only represent three-dimensional objects in a single texture and fail to offer a realistic depiction of the real world. Furthermore, the need for current and precise geographic information regarding urban areas has been increasing significantly. This study proposes a new technique to address this problem, which involves integrating remote sensing, Geographic Information Systems (GIS), and Architecture Environment software environments to generate a detailed three-dimensional model. The processing of this study starts with: 1) Downloading high-resolution satellite imagery; 2) Collecting ground truth datasets from fieldwork; 3) Imaging noise removing; 4) Generating a Two-dimensional Model to create a digital surface model in GIS using the extracted building outlines; 5) Converting the model into multi-patch layers to construct a 3D model for each object separately. The results show that the 3D model obtained through this method is highly detailed and effective for various applications, including environmental studies, urban development, expansion planning, and shape understanding tasks.

## Keywords

World View-3 Satellite Image, Sketch Up, Digital Surface Model, 3D Buildings

## 1. Introduction

Digital Surface Models (DSMs) are an essential component of Very High Reso-

lution (VHR) satellite stereo photogrammetric imagery. Three-dimensional (3D) information is critical for numerous geospatial analyses, which can be integrated into Geographic Information Systems with accurate georeferenced datasets [1] [2] [3]. The development of spaceborne sensors has enabled the acquisition of VHR stereo data in a timely and repeatable manner for any region of interest, making it more affordable than traditional aerial surveys. According to [4] [5] [6] [7], the quality of stereoscopic DSMs depends on three factors: 1) The radiometric and geometric quality of the imagery; 2) The accuracy of the sensor model used to represent the relationship between image and object space; 3) The performance of the image matching algorithm. Recent research on extracting 3D information from VHR satellite stereo pairs has mainly focused on Digital-Globe's VHR satellites, such as GeoEye-1 and WorldView-1/2/3/4, which can capture panchromatic imagery of the land surface with a ground sample distance (GSD) even lower than 0.5 m [8]. Other studies have also examined the capabilities of the Pléiades-1 PAN triplet for generating DSMs [9]-[14]. The accuracy of the DSM also depends on the sensor model used in the stereo pair orientation phase, with either the rigorous linear-array model or the parametric rational polynomial function model (RPF) being commonly used [15] [16] [17] [18]. The RPF model, which uses 78 parameters called Rational Polynomial Coefficients (RPCs), is preferred over the rigorous model as it achieves similar accuracy levels and is more compatible across different sensors. However, the initial RPC parameters from the satellite navigation system may contain bias, and bias-correction is necessary to generate precise epipolar images for dense image matching, which can be performed either using tie points for relative correction or accurate ground control points (GCPs) for absolute correction [19] [20] [21].

Various software packages are available for generating Digital Surface Models (DSMs) from Very High Resolution (VHR) satellite images. These include commercial packages such as MATCH-T from Trimble, LPS eATE from ERDAS, and Socet Set ATE from BAE Systems, as well as open source tools such as Satellite Stereo Pipeline (S2P), the NASA Ames Stereo Pipeline (ASP), and Digital Automatic Terrain Extractor (DATE). OrthoEngine, the photogrammetric module of Geomatica, is the most commonly used package in research and is used as a benchmark for comparison tests in studies [22].

Matching methods play a crucial role in generating DSMs, particularly in urban environments. Alobeid *et al.*, [23] found that the area-based least squares matching method is not able to generate sharp building outlines and is strongly impacted by occlusions. On the other hand, semi-global matching (SGM) and dynamic programming matching methods achieve better results in urban areas. DSM accuracy can vary depending on the surface roughness and target land-cover objects. Many studies have explored DSM generation from VHR satellite images in different environments, including urban areas flat bare soil [24], mountainous areas [25] [26] [27], densely vegetated deciduous forest, glaciated regions, and herb and grass land cover [28] [29] [30] [31] [32]. However, few stu-

dies have focused specifically on greenhouse-covered areas [24], where accurate 3D extraction is challenging due to the varying properties of the plastic materials used.

The accuracy of a DSM generated from VHR satellite images is typically evaluated using highly accurate Light Detection and Ranging (LiDAR) information as ground truth. However, matching errors caused by insufficient texture, occlusions, or radiometric artifacts can lead to inaccuracies in the generated DSM. Therefore, the quality of a DSM should also be evaluated based on its completeness, which is defined as the percentage of correctly matched points over the area of interest [33]. Incorporating DSM or Normalized Digital Surface Model (nDSM) information into pixel-based and object-based supervised image classification algorithms can significantly improve the accuracy of greenhouse mapping [34].

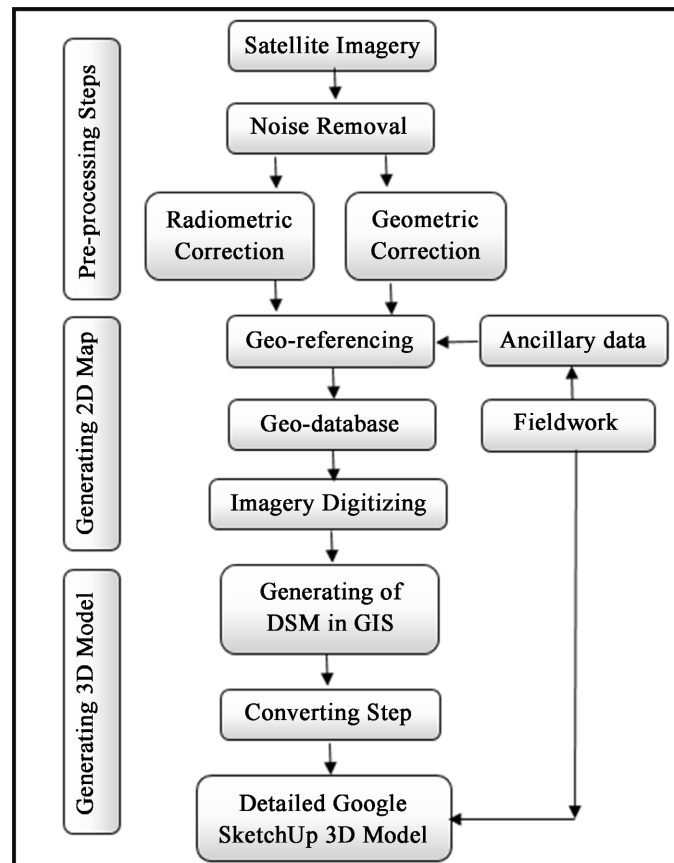
The primary objective of this study is to create an accurate and highly detailed 3D model of a college campus that closely resembles the real world. Additionally, the research aims to investigate the effectiveness of integrating ArcGIS and SketchUp models to create a site-linked 3D faculty campus.

## 2. Method and Material

The study utilized a methodology to produce detailed 3D models of the Agriculture Faculty campus, starting with the acquisition of high-resolution satellite imagery and collecting ground control points (GCPs) through fieldwork. The collected data was then used to perform geometric and radiometric corrections and geo-referencing to the satellite imagery. A geodatabase was created in Arc Map 10.3v, and digitization was conducted to obtain a shapefile of the study area's buildings and additional data about their names and heights. The resulting 2D map generated in Arc Map was applied in the Arc Scene platform to produce a DSM using features attributes. The Google Sketch Up Environment was then used to create a 3D model of each object in the study area by converting the DSM file extension from Arc Scene to Google Sketch Up, and capturing photos of the main campus. **Figure 1** depicts the methodology used for this study.

### 2.1. Study Area

The study area is Agriculture Faculty campus one of the faculties of Al-Qasim Green University. The location of the Agriculture Faculty in longitude and latitude of 44°40'38.30"E and 32°18'21.25"N. College of Agriculture, Al-Qasim Green University, formerly known as the College of Agriculture, University of Babylon, is one of the scientific colleges at Al-Qasim Green University. It specializes in teaching scientific and engineering subjects related to agriculture, methods of increasing agricultural production, and addressing production problems. It also teaches soil science and water resources from physical, chemical, and biological perspectives. The college was founded in 2004 and was initially affiliated with the University of Babylon before becoming part of Al-Qasim Green



**Figure 1.** The 3D mode and DSM methodology flow chart.

University. It is area approximately 2 km<sup>2</sup>, as shows in **Figure 2**.

## 2.2. Datasets

For this study, the dataset utilized consisted of a WorldView-3 satellite image, as well as ancillary data of the study area and data collected during fieldwork. The study area, illustrated in **Figure 3**, measures approximately 2 km<sup>2</sup>. The National Oceanic and Atmospheric Administration (NOAA) licensed the WorldView-3 satellite sensor, which collects eight-band short-wave infrared (SWIR) and 12 CAVIS imagery in addition to standard panchromatic and multispectral bands. This commercial satellite sensor operates at an altitude of 617 km and provides a spatial-resolution of 31 cm for panchromatic, 1.24 m for multispectral, 3.7 m for short-wave infrared, and 30 m for CAVIS resolution. With an average revisit time of less than one day, the satellite is capable of capturing up to 680,000 km<sup>2</sup> per day. The image used in this study was taken on October 15, 2022 over AL-Hilla city, Babil province, Iraq, and has been corrected for both radiometric and geometric accuracy to reduce noise. The WorldView-3 image and study area are depicted in **Figure 3**.

## 2.3. GCPs Collecting

During this phase of the study, it was necessary to collect ground reference

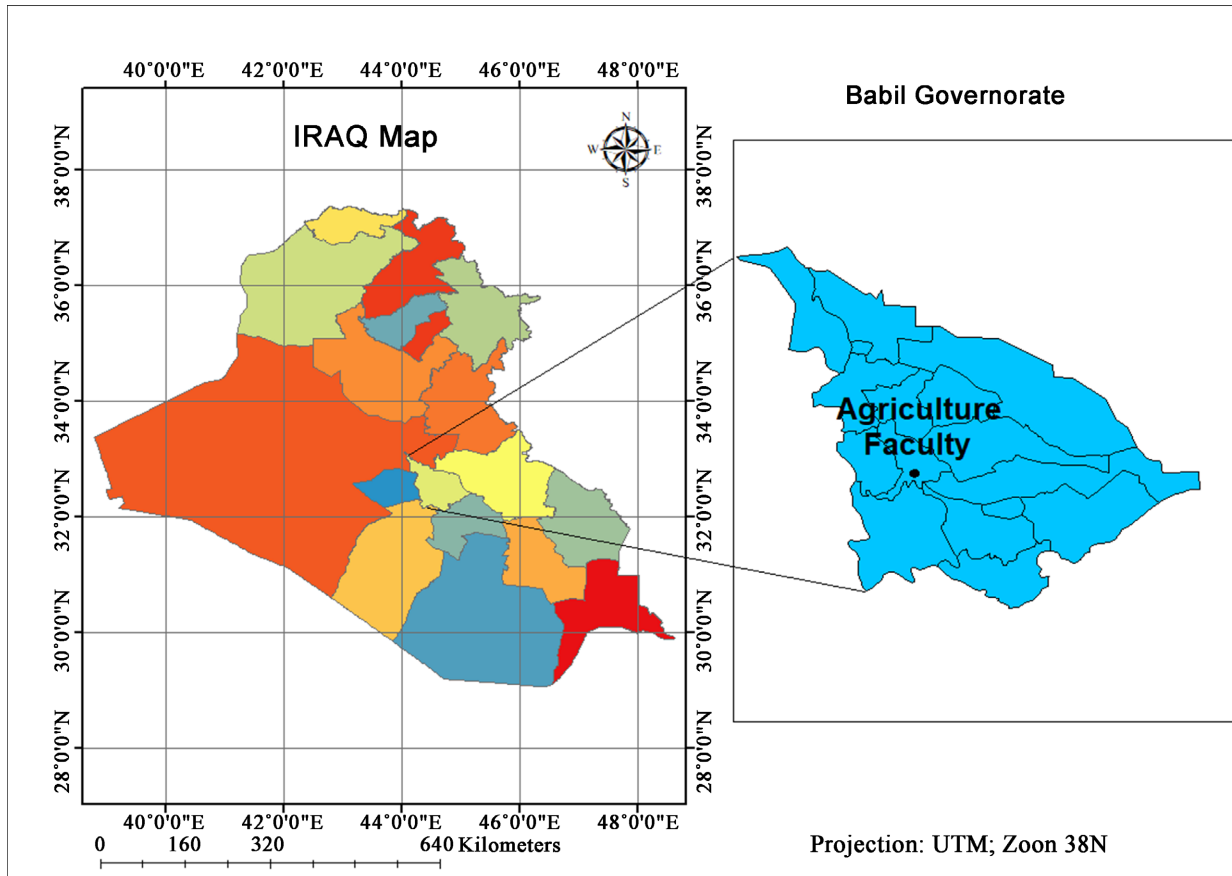


Figure 2. The study area location.



Figure 3. The WorldView-3 satellite image of the study area.

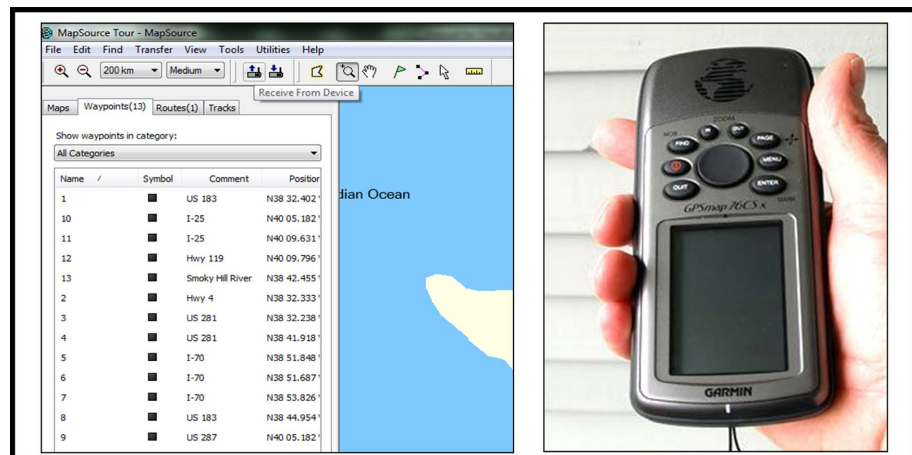
points to enable the geometric correction of subsequent stages. To achieve this, fieldwork was carried out using a Garmin Csx76 global positioning system device to obtain GCPs for certain features located within the study area. **Figure 4**

depicts the features in question. On January 15, 2022, fieldwork was conducted to record eight GCPs surrounding the Agriculture College, and the information gathered is presented in **Table 1**. Additionally, photographs of the college campus were taken during this phase to facilitate the creation of a 3D model of the area of interest.

### 3. Geometric and Radiometric Corrections

The geometric errors in satellite images can be caused by a number of factors such as sensor distortion, satellite orbit inaccuracies, and terrain distortions. These errors can result in misalignment, image stretching, and other anomalies that can affect the accuracy of the image analysis. Here are some steps to remove geometric errors from satellite images [1] [2] [3]:

- 1) Use ground control points (GCPs): GCPs are physical features on the ground with known coordinates that are used to register and rectify the satellite image. These can be features such as roads, buildings, and other landmarks that can be identified on both the satellite image and a reference map.
- 2) Use image matching techniques: Image matching involves identifying



**Figure 4.** Handheld GPS device type Garmin Csx76.

**Table 1.** The fieldwork of selected GCPs.

No.	points	Northing	Easting
1	A	32°23'56.67"N	44°24'07.16"E
2	B	32°23'52.88"N	44°24'06.52"E
3	C	32°23'53.60"N	44°23'59.31"E
4	D	32°23'58.53"N	44°24'00.34"E
5	E	32°23'55.26"N	44°24'01.15"E
6	F	32°23'56.02"N	44°24'01.80"E
7	G	32°23'54.86"N	44°24'03.22"E
8	H	32°23'55.15"N	44°24'04.77"E



common features in two or more images, such as buildings, roads, or other landmarks, and using them to align and rectify the images. This technique is particularly useful for removing geometric errors caused by satellite orbit inaccuracies.

3) Apply geometric correction algorithms: Geometric correction algorithms such as polynomial, affine, or projective transformations can be used to rectify the image and remove geometric errors. These algorithms use GCPs and other information about the satellite sensor and orbit to transform the image to its correct position and orientation.

4) Use image processing software: There are various image processing software packages available that can help remove geometric errors from satellite images, such as ERDAS Imagine, ENVI, and ArcGIS.

Verify the accuracy of the corrected image: Once the image has been rectified, it is important to verify the accuracy of the corrected image by comparing it with reference maps and other ground truth data to ensure that the geometric errors have been successfully removed [2] [3] [4] [5]. The geometric correction of this study was done using the GCPs with use the first order polynomial transformation, the ENVI environment was used to remove the noises from the WorldView-3 satellite image and it was done by selecting the feature that located in the imagery and enter the coordinate value of corresponding feature as indicates in **Figure 5**. In the study area, the radiometric correction was performed using the Quick Atmospheric Correction (QAC), the collected GCPs and final and corrected satellite image shown in **Figure 6** below.

## 4. Results and Discussions

In section 2 of the study, the research processing was conducted in three stages. The first stage was the pre-processing step, which involved the acquisition of



**Figure 5.** Side of geometric noise remove using GCPs in Envi.



**Figure 6.** The Final corrected satellite image.

high-resolution satellite imagery of the study area from the WorldView-3 satellite, as mentioned in section 2.2. Radiometric and geometric corrections were then performed to reduce image noise captured in the images. In the second processing stage, the WorldView-3 satellite imagery was geo-referenced by matching the coordinates of ground control points collected during fieldwork with their corresponding locations in the satellite image. The digitization of the satellite image was then carried out to obtain the footprint (2D map) of the study area, generating five layers with different information, including buildings, gardens, streets, boundaries, and trees within the Faculty campus. Attribute tables were established for each layer, with a height field added to generate the university campus DSM and create a 3D model in the next steps. The final output shapefile of the study area is shown in **Figure 7** and **Figure 8**. The results of the study revealed that while the traditional 2D map provided a base map for future work, it was flat and had limited effectiveness for individual building data extraction due to its poor shape understanding. [31] [32]

The third stage of the research involved post-processing, with a focus on obtaining a detailed 3D model of the study area, which is the Faculty campus. The initial step in this stage was to create a DSM using the Arc Scene environment by applying the generated shapefile from the previous step. The third dimension (height) was then added based on the features' attribute using Arc Scene environment. The resulting DSM was created using this method, as shown in **Figure 8**, which depicts the university campus's generated DSM [33] [34]. **Figure 9** Show the generated 3D model in GIS

Based on the experimental results, it has been demonstrated that the final 3D model is more precise and detailed than the DSM. The final 3D model can be utilized in Google SketchUp and the Arc Scene environment by replacing the Collada's geometry file in Arc Scene with the one generated by Google SketchUp. Integrating GIS with SketchUp enables the effective utilization of all



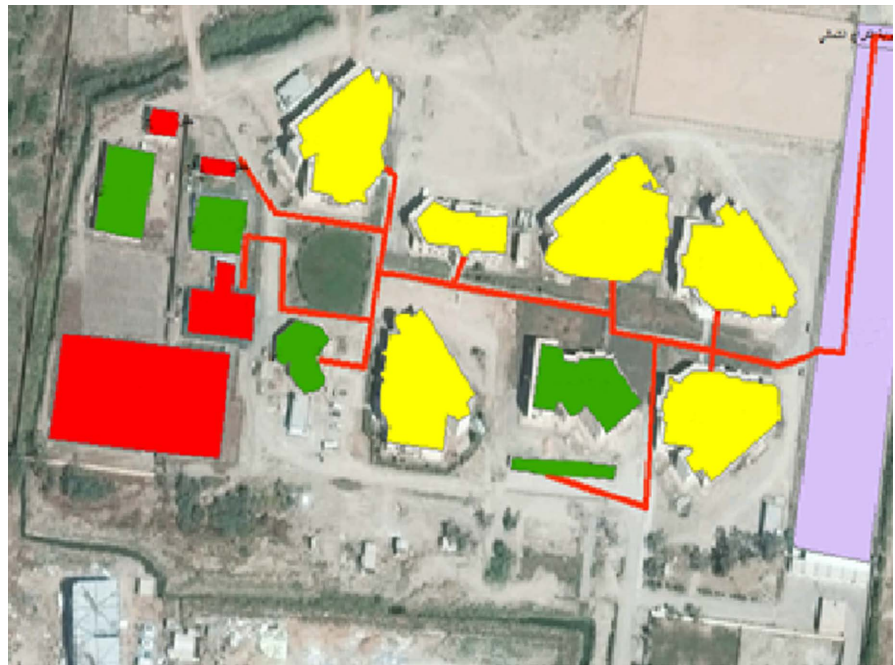


Figure 7. Digitizing processing of satellite image.

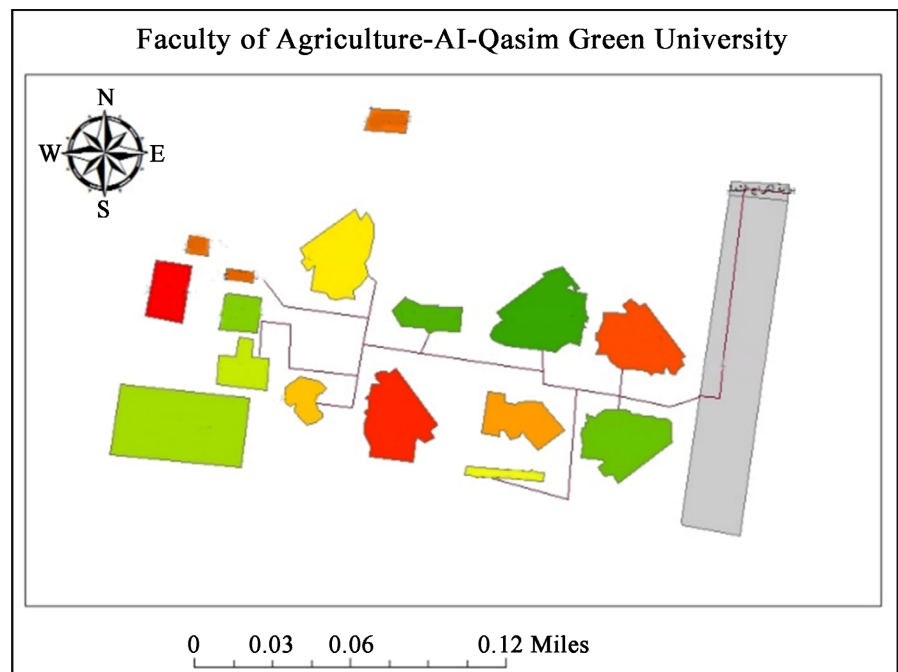
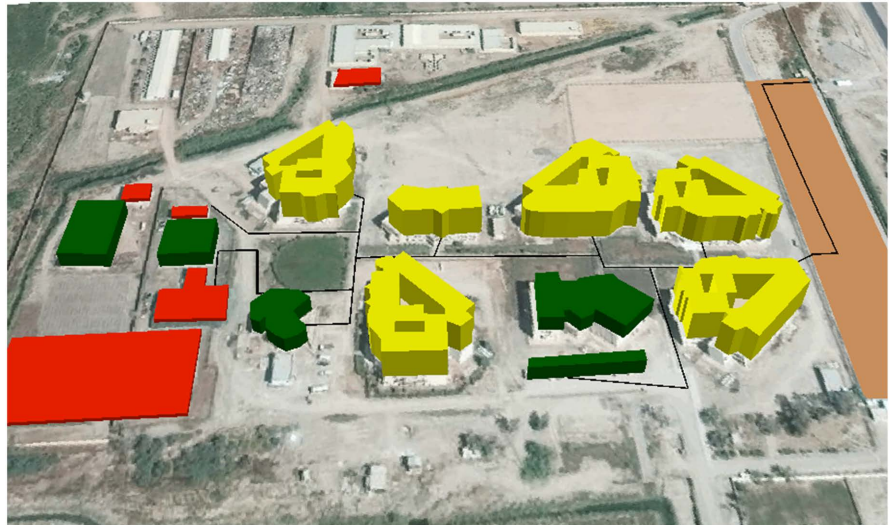


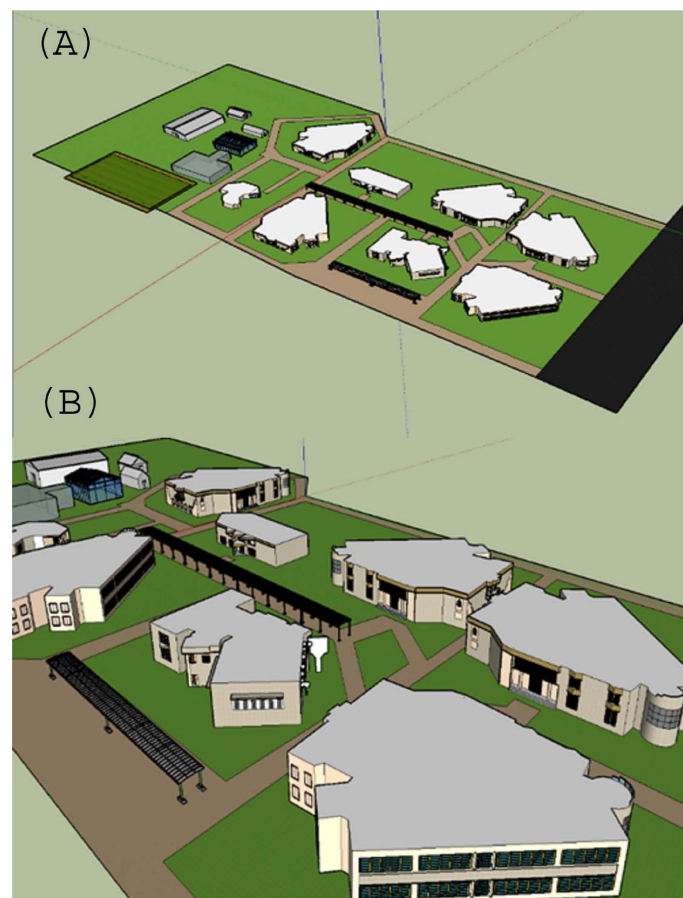
Figure 8. The 2D map of agriculture faculty.

necessary geographic information for all buildings and features located in and around the university campus. The established attributes provide users with the required information for any future work to develop the study area. This integration enables a smoother model export and import among different software and offers a richer performance of the campus model. It is, therefore, crucial for facility management to effectively link the building model to the site model, pro-

viding a realistic view for visitors, adapting to in-progress changes, and allowing for better visualization and analysis of data for existing buildings. **Figure 10(A)** & **Figure 10(B)** show the 3D detailed Model of the study area in Agriculture Faculty, AL-Qasim Green University [28] [33] [34] [35] [36].



**Figure 9.** The DSM of agriculture faculty.



**Figure 10.** The detailed 3D buildings model of agriculture faculty.

**Figure 10** reflect how much the SketchUp enables users to create detailed 3D models that accurately represent their vision. One of the standout features of SketchUp is its intuitive user interface, which makes it easy for designers of all levels to create detailed 3D building models. With a variety of tools and functions at their fingertips, users can easily manipulate objects and shapes to achieve the desired effect. Whether they're creating a simple box-shaped structure or a complex, multi-level building, SketchUp provides the tools and functionality needed to get the job done. Another key advantage of SketchUp is its ability to import and export a wide range of file formats [21].

## 5. Conclusion

In modern geospatial needs, having a DSM and/or DEM in a single color and texture is no longer sufficient. To address this issue, a novel technique is presented in this study, which involves three main steps. Firstly, pre-processing is performed by correcting the satellite imagery radiometrically and geometrically. In the processing step, ancillary and fieldwork datasets are utilized to georeference the study area image, create a geodatabase, and digitize the image to generate a 2D map of the university campus. DSM is obtained using different software tools like ENVI, Arc Map, and Arc Scene environments throughout the pre-processing and processing steps. Finally, in the post-processing step, the DSM's extension file is converted to a format compatible with the Google SketchUp environment, which is then used to create a 3D model based on the DSM created in the previous steps. The obtained 3D model provides researchers with more detailed information and a view that is more realistic. The 3D model's final results exhibit a perfect representation of the study area and demonstrate the effectiveness of obtaining a 3D model compared to obtaining a DSM. There are some limitations when conducted this work: 1) It is difficult to get photographs that cover the entire buildings; 2) Finding DEM has spatial resolution reach to 0.10 cm difficult; 3) In case if need to use UAV in Campus, needs to get many permissions. The highly detailed information obtained from the 3D model can be applied to a variety of applications such as environmental studies, urban development and expansion planning, and diverse shape understanding tasks.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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