3-D model development case study at Troy University

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ABSTRACT

The development of GIS applications has over the years been increasing. The visualizations of the end results from such GIS applications form part of the end-product that is used in the final output. In this paper is presented a discussion of the procedure and results adopted for the development of a three dimensional (3-D) model of the Troy University Campus, located in Troy, Alabama, USA. Further processing the CAD data sets into a format useable for the generation of a 3-D model of the campus is presented. The processing included further enhancements such as adding an orthophoto, and the draping other physical features such as extruded buildings to make the model as realistic as possible. Updates to the CAD file were done by making use of field surveys which included adding the new changes to the University campus. Problems and their solutions of the entire approach are critically reviewed.

1.0 Introduction

The use of Geographic Information Systems (GIS) has over the years been increasing as seen through the variable use of its applications together with its increase in the volume of geodata sets. The visualization of the end results from such GIS applications is part of the end-product that is made available from the output of the typical end-results.

The demand for diverse computing capabilities has also been increasing when comparing present day computers to that of early computers. There are many inventors who have contributed to the history of computers. It is know that a computer is a complex piece of machinery made up of many parts, each of which can be considered a separate invention. In 1981 Microsoft DOS was developed as the operating system for IBM PC, while in 1985 Microsoft Windows was the attempt of Microsoft Cooperation to develop a similar work environment as Apple Cooperation computers. Presently there are many operating system Linux, which stems from UNIX (developed in 1969 as a private research project), windows, XP. The various processing flexibilities provided by the operating systems have certainly been increasing with the increased processing capabilities facilitated by the computer.

GIS is a relatively new emerging Information Technology (IT) which has promising large scale influences in how spatially distributed resources are managed. GIS technology has been rapidly evolving into practical applications for municipal, public, and private agencies during the past two to three decades. During such time significant attention has been given to the use of various information system technologies to promote service delivery.

Internet Explorer is Microsoft's World Wide Web (WWW) browser, and the name for a set of Internet-based technologies that provide browsing, email, collaboration and multimedia features to millions of people around the world (Scott 2001[1]). GIS has developed to the extent where data sharing via the WWW is slowly becoming a concept of the past because emphasis is now on the application development and processing of spatial data sets. A common GIS application development area is in the area of three-dimensional (3-D) models.

In this paper is presented a few examples of 3-D models, after which a detail description of the Troy University case study development of its 3-D model. This case study started as a student project from which the idea to generate a 3-D model of the university's campus was developed.

2.0 Three dimensional models

The use of GIS has been extended to include the third dimension where users are requiring that their spatial data sets can be best viewed realistically if placed in the real world setting. One of the common 3-D models is a comprehensive land-related information system which includes land use, buildings, flood hazards, income levels, population at the parcel level, and such like. Applications which are developed by the Environmental Systems Research Institute (ESRI) typically use the out of the box ArcGIS with the 3D Analyst or ArcGlobe extension. In Figure 1 users can identify the features and highlight the results three dimensionally. Multiple views of the 3D model can be viewed using such extensions. Queries can be made and the results can be displayed on the planar surface and then extruded to the 3-D surface.

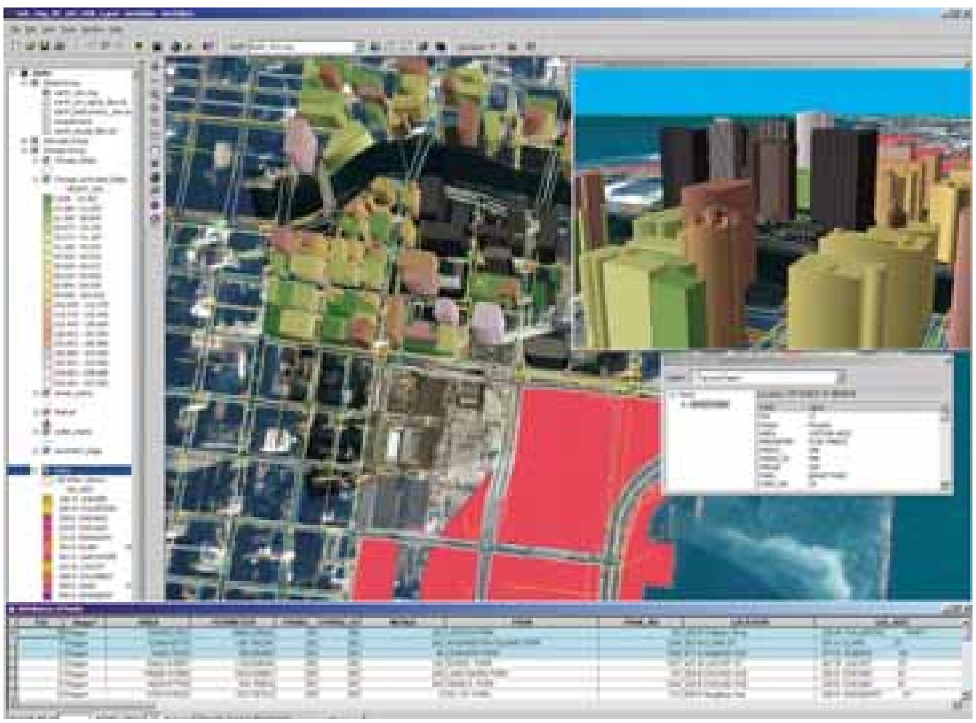

Figure 1: ArcGlobe 3-D application[2]

The ability to take the GIS data sets and display them in a manner which is realistic enough to mimic reality indicates the growth and enhancement of GIS. This is one of the many demands of GIS development and it is this demand that this paper is based upon.

[1] http://www.nwnetworks.com/iehistory.htm
[2] http://www.esri.com/news/arcnews/summer03articles/introducing-arcglobe.html

3.0 Case study

The intent as presented in this paper is to make use of an existing Computer Aided Drawing (CAD) file which was captured by the Physical Plant Department at Troy University and to identify the drawbacks in their approach of data capture, and to structure the data in a manner which can be used in achieving our objective of generating a 3-D model of the Troy University campus. This has not been done before and this paper's objective is to identify the pros and cons of the approach and the difficulties experienced by making use of the already captured data sets. Many organizations make use of CAD files which would typically require further processing in order for the data to be used in other software. For example CAD files are sometimes required to be further processed as follows:

- Store points, lines, and polygons on separate layers;
- Similar features from reality must be stored in the same layer;
- Export CAD files as a Digital Exchange File (DXF) format;
- Separate the features into unique feature class layers;
- Edit errors to ensure that labels are attached to correct features, polygons are closed, dangle lengths are removed; and
- Coordinate systems are defined and transferred when data sets are exported.

Traditionally, CAD files are commonly found in organizations (utilities, mapping agencies, and such like), that are typically focused on creating maps because they are not into the business of analyzing data but more into the display and presentation of data. The introduction of GIS has certainly extended the responsibilities of such organizations by making use of their large pool of data sets to assist in their decision making processes. One organization which can benefit from such an innovative use of its data sets is Troy University.

3.1 Troy University

Troy University is an accredited University which was founded in 1887. Troy University is located in 11 countries, 17 states, and there are 60 campuses[3]. Its main campus is located in Troy, Alabama. The campus provides a well-credited faculty who know their students by name rather than a student ID, and the academic offerings prepares the students for numerous professional careers.

The Geomatics Program at Troy University was founded in 1998. The number of graduates each year is not enough to satisfy the demand for qualified people in the Geomatics field. Students get jobs even before they graduate from the University. Students are exposed to the wide Geomatics field which includes Land Surveying, GIS Photogrammetry, Remote Sensing, Hydrology, Land Law, and such like. Students initially join the Geomatics Program to get their Land Surveying license however they sooner find out that their professional choices are broad and diverse as defined by the Geomatics field. One of the rapidly developing areas is GIS.

3.2 CAD file

The CAD file used in this paper was obtained from the Physical Plant in Troy University. The Physical Plant is responsible for the maintenance and support of the University amenities necessary for its everyday operations. To help them in their responsibility, they have captured the entire campus using AutoCAD 2003. Figure 2 shows the CAD file captured with its multiple layers. The topographic maps captured were at a scale of 1inch = 50 feet, contour interval was at one foot, and the date of data capture was April 2002. The UTM Zone 16 coordinate projection system was used on the topographic map and so was the digitized CAD file.

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[3] http://www.troy.edu/quickfacts.htm

On examining the CAD file it is clear that the intent of the Physical Plant was to capture and display a digital map. They have certainly achieved their objective however the further processing of their data set was halted, unless a systematic redefinition and separation of the features are done to separate layers. This is particularly important if the data sets are to be used in a GIS. The following is a list of the drawbacks of the CAD file:

- Contour lines were not continuous – the lines were broken when passing through buildings and where texts were placed
- Road edges were not continuous – the lines were broken when they passed under tree cover
- Clutter map – the features and texts collectively made the map difficult to read
- Layers – the definition of the layers were not explicitly define as shown in Figure 2
- Features digitized – all of the contents of the topographic maps were digitized

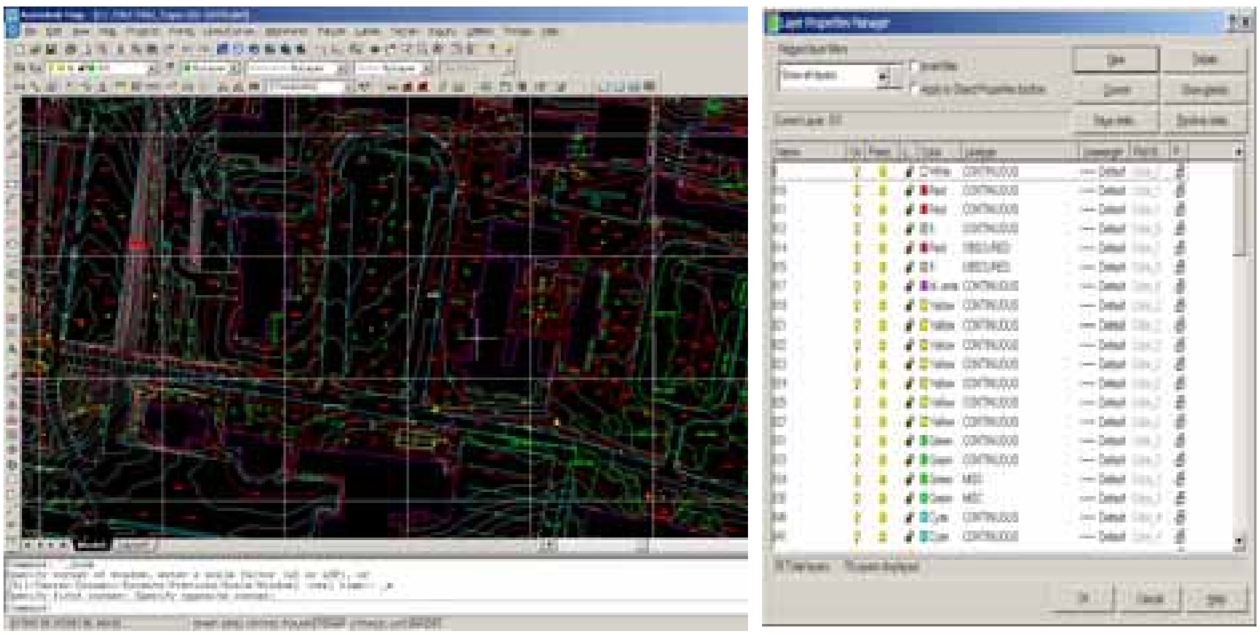


Figure 2: CAD drawing and its multiple layers

The drawbacks are what need to improve upon if we are to be successful in the migration of the CAD file into a GIS.

4.0 Procedure

ArcGIS 9.0 is the GIS software which is used to generate the 3-D model of the campus. The ArcScene module was used to vary the view of the 3-D model. The steps used to generate the model are identified as follows:

a) Layer separations

The layers in the CAD drawing were not named intuitively but instead, three digit numbers were used. The CAD file did not contain any metadata or data dictionary, apart from what was shown in the CAD file. Each layer had to be determined as to what they represented and from this, separate CAD files were created. The coordinate system used to capture the features made use of NAD 1983 UTM Zone 16N projections system which was digitized in AutoCAD. The coordinates were presented using Eastings and Northings.

b) Geodatabase generation

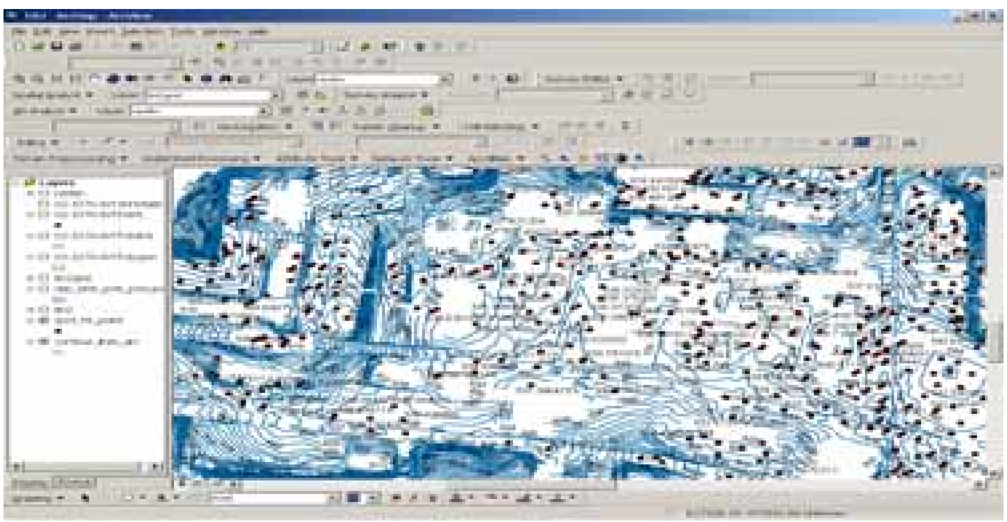
A geodatabase was created using ArcCatalog in ArcGIS 9.0. Each CAD layer was imported into the geodatabase using the ArcToolbox conversion toolset. The layers added were contours, spot heights, buildings, and roads.

c) Importing feature classes

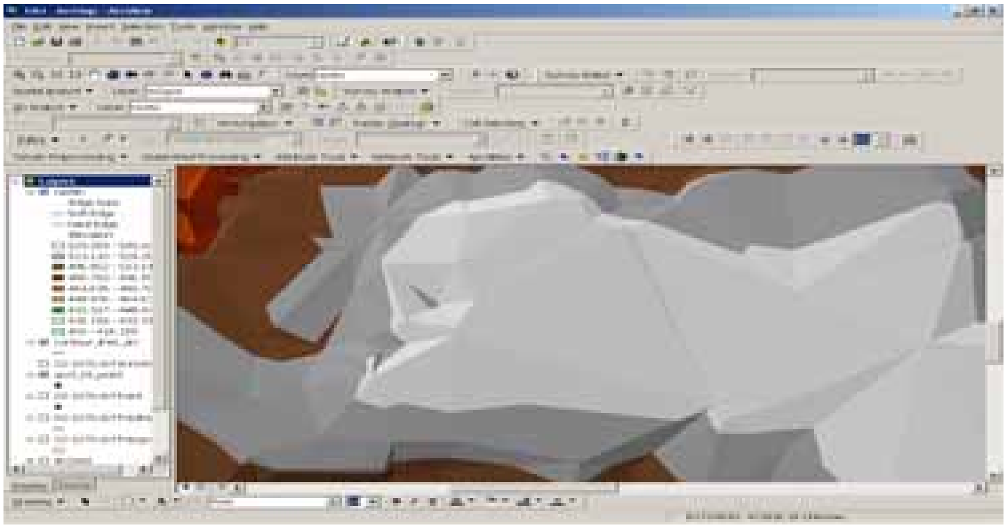
The CAD layers were converted into feature classes when they were imported into the geodatabase. A new ArcGIS project was created using ArcGIS. The data sets are added later into an ArcMap's project file format (.mxd). The coordinate system (NAD 1983 UTM Zone 16N) was set for all the feature classes so that they are easily georeferenced.

d) Triangular Irregular Network (TIN) generation

The Contours feature class was checked to see if the height information were correctly linked to the line feature they represented. The Spot Height feature class was also checked for its consistency with it height information shown in its attribute table. A Triangular Irregular Network (TIN) was created using these two feature classes which is shown in Figure 3.



(a) Contour lines and spot heights



(b) TIN representation

Figure 3: Contours and TIN representations of Troy University campus

e) Digital Elevation Model (DEM) creation

The DEM is generated from the TIN by using the Spatial Analysis extension from ArcGIS 9.0. The cell size is 30 x 30 meter

f) Georeferencing aerial photo

An aerial photo of the Troy University campus was obtained and was rectified using the ground control of defined points from existing feature classes. The rectification was done using the georeferencing toolset from the ArcGIS software.

g) Draping of feature classes

The feature classes draped were the converted CAD layers extracted from the CAD file. The feature classes added were the vector data of the buildings that were further extruded, and then a 1990 aerial photo of the Troy University campus.

h) Data set updates

The quadrangle area of Troy University was initially a car park with an open area. In recent times the area was remodeled to exclude the parking area and improve the quadrangle aesthetically, by having a water fountain, trees, and grassy areas. The updates were done by our Geomatics students as a project for the Introduction to GIS course. They made use of TOPCON total stations to capture the changes made to the quadrangle. The changes captured were the foot-walks, water fountain, and trees. These updates were added as feature classes into the data frame of this ArcGIS project.

i) 3-D model of Troy University

The 3-D model was generated using a computed digital elevation model (DEM). The DEM is the important raster surface which provides the height information in the 3-D model. The DEM was created using the TIN generated from contour lines and spot heights that were captured and stored in the CAD file. The conversion toolset in ArcGIS was used to generate the DEM. The DEM was then imported into an ArcGIS geodatabase as a feature class. The coordinate system was made consistent with the other feature classes obtained for Troy University.

5.0 Quality issues

The data quality issues in the procedure identified in this paper is categorized as being specific to the micro level of the individual CAD data set. Since the data was collected with the initial intent of capturing and converting the content of the topographic map of the Troy University campus into digital format, then it has certainly satisfied its initial objective. However, in using this CAD file for the generation of the 3-D GIS model, some short-comings are identified.

In the creation of any DEM, the original height information must be accurately presented. For a good DEM is determined by:

- the concentration of the contour lines (small contour interval);
- the identification of a dense network of spot heights;
- the location of critical points/lines where there are sudden elevation changes, and also constant elevation;
- the algorithm used for height interpolation; and
- the ability to control the DEM form by the use of critical points/lines.

The influencing data quality issues that affects the DEM used in this paper is specifically related to the CAD file. The specific short-comings of the CAD file are due to the fact that the CAD digitizing was done without any projected plan to use it in any other third-party software. The short-comings are as follows:

- the naming convention of the CAD layers did not have any metadata (which is not possible in AutoCAD);
- the contour lines were broken at the areas where their contour values were input as text from the topographic map;
- the contour lines were broken at the locations of buildings and vegetation;
- the size of the vegetated areas are not accurate in terms of their spread and coverage areas;
- the parameters of the datum used in defining the coordinate system is not explicitly defined;
- the new additions to the CAD file is depended upon the contents on the topographic map; and
- the addition of similar features on different CAD layers.

The improvements to the short-comings were minimized by adopting the above mentioned procedure. This was possible because of the clear understanding of what is needed in the creation of a 3-D model. The creation of a 3-D model has been done in many GIS applications. If the original intent was to create a 3-D model by the Troy University Physical Plant, then most of these short-comings could have been avoided, however, their intent was not as such.

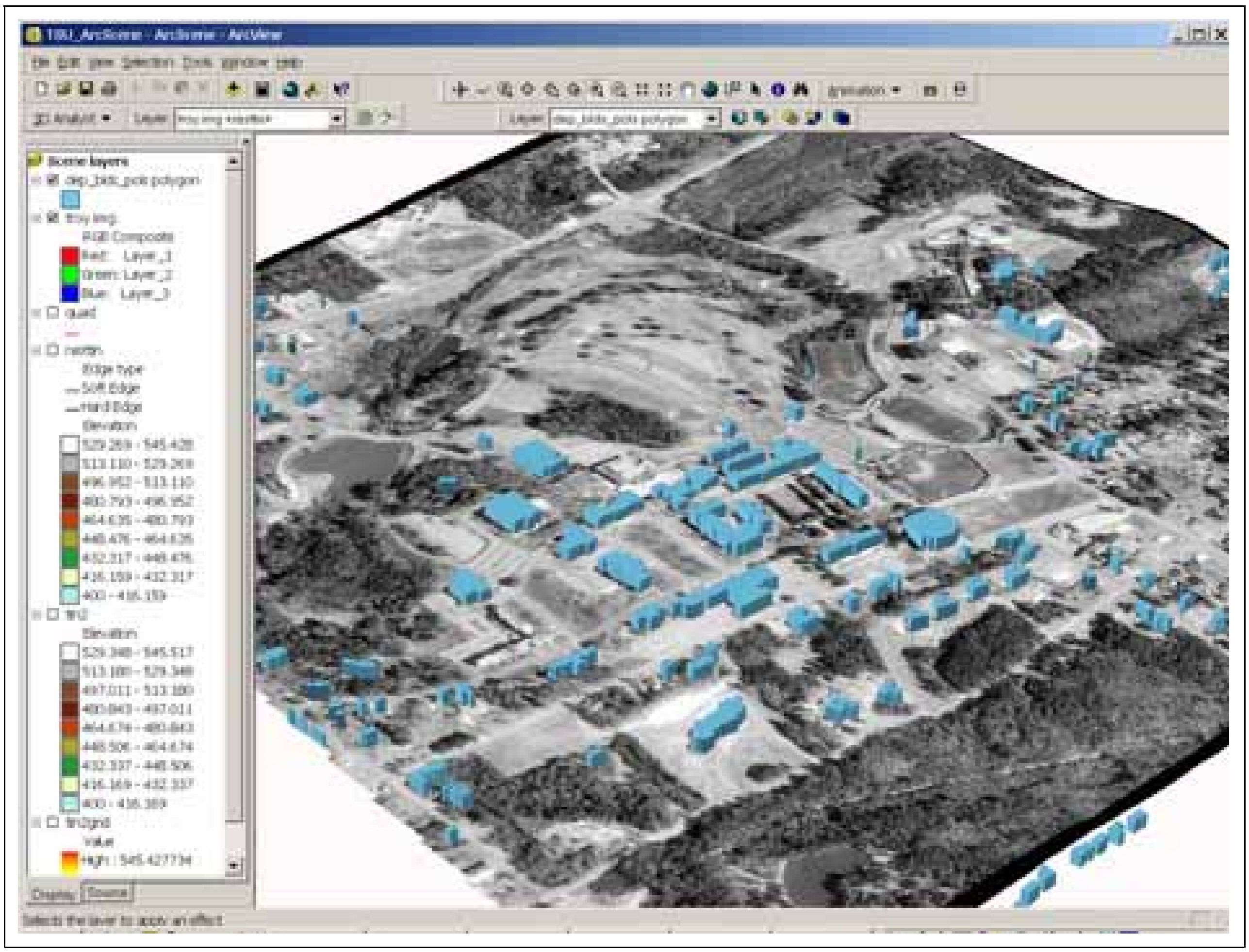
6.0 Results and conclusions

The result from the adopted procedure in generating the Troy University 3-D model is shown in Figure 4.0. The entire campus is shown with the buildings extruded and the aerial ortho-photo draped over the DEM. The area shown at the bottom of the entire Troy University Campus is the quadrangle area, before and after the update. The before view shows the quadrangle with it old car park area, while the new view shows the Total Station survey of the new quadrangle integrated with the CAD data.

The result from this paper shows that the creation of a 3-D model for the Troy University campus is possible within the limitation of the quality of a captured CAD file. The 3-D model can be improved by draping the following CAD layers as feature classes onto the DEM:

- roadways and footpaths;
- people, cars and parking lots;
- improve the building extrusions by using the true outside building texture;
- add the effect of the sky and the sun; and
- create animation files which will be used on the Troy University website as a recruiting tool.

Given the quality of the original CAD file, the generated 3-D model is a good representation and it can be further improved and used in other possible GIS applications which are specific to the Troy University campus.



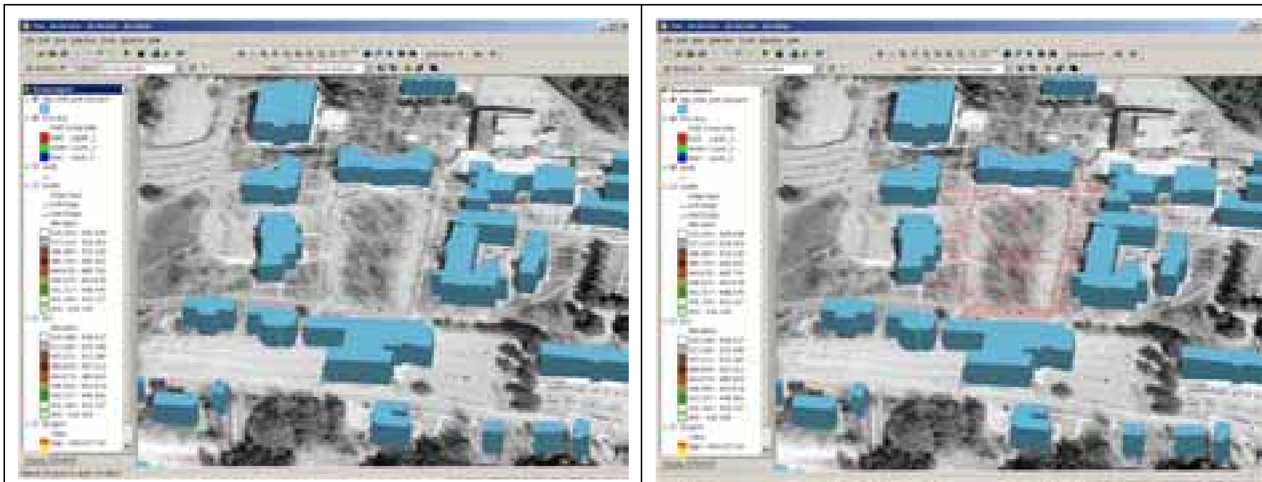


Figure 4.0 The 3-D model of Troy University Campus