بسم الله الرحمن الرحيم

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COLLEGE OF GRADUATE STUDIES

Computer Science and Information Technology

Three-Dimensional modeling with Texture Mapping for Khartoum International Airport

نمذجة ثلاثية الأبعاد مع خريطة الملمس لمطار الخرطوم الدولي

A Thesis Submitted in Partial Fulfillment of the Requirements of
Master Degree in Computer science
(GIS Geographical Information Systems)

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الأية

بسم الله الرحمن الرحيم

قال تعالى {وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ}.[هود: 88]

صدق الله العظيم

Dedication

This thesis dedicated to my parents, brothers, sisters, classmate's and my supervisor

For their endless love, support and encouragement

ABSTRACT

According to the great urban progress in the country and permanent renewal of buildings in line with modern developments an update of 3D building infrastructures becomes a necessity. Especially universities, hospitals and airports buildings are of main concern, which are changing continuously as well as offices and halls according to the requirements of the country and by adding new buildings. Passengers are suffering for knowing places of offices, halls and how to reach it, especially the new passengers.They are wasting their time in asking a way to reach a particular place inside the airport - this could have a negative effect on the traveling time or the completion of the registration procedure on time. Therefore, any plan and project to assist the airport administration to develop the airport and the provision of passenger's. Starting off from that point, different ideas and techniques grew up to make the geographic orientation easier for Passenger and guiding them to reach a particular place in due time. For this reason, the need of applying three-dimensional visualizations with texture mapping is the true simulation of reality- this is called Virtual Reality Model (VRM). On the other hand, this thesis aims to take advantages of GIS environment to offer a flexible interactive system for providing the best visual interpretation, planning and decision making processes for Khartoum International Airport.

المستخلص

نسبة للتطور العمراني المشهود في الآونة الأخيرة والتجديد الدائم للمباني بما يناسب التقدم الحديث، خاصة بمباني الجامعات والمستشفيات و المطارات مثل المكاتب والصالات بما يستلزم المتطلبات للدوله بتجديد واضافه مباني ، اصبح لابد من توفر بنية ثلاثية الأبعاد لتوضيح تلك المباني. يعاني المسافرين وخاصة المسافرين لاول مره ، من صعوبة معرفة اماكن المكاتب والصالات وكيفية الوصول اليها خاصه في فترة التسجيل أو الاجراءت . يهدر المسافرون الوقت بالسؤال عن طريق الوصول الى مكان معين داخل المطار مما قد يؤثر سلبا على زمن وصولهم في الزمن المحدد او اكمال إجراءات السفر في الوقت المحدد.انطلاقاً من ذلك نشأت افكار وتقنيات مختلفة للتسهيل على المسافرين والإداره للوصول للأماكن المراده في الوقت المحدد.لذلك ومن هنا ظهرت الحاجة لتطبيق الخرائط والنماذج التصويرية ثلاثية الابعاد وهي محاكاة حقيقيه للواقع والتي تعرف بـ (VRM). من ناحية اخرى يهدف البجث للاستفاده من انظمة المعلومات الجغرافيه(GIS) في توفير بيئه تفاعلية مرنه لتقديم افضل نموزج تصوري لمطار الخطوم الدولي للاستفسارات والتخطيط والمساهمه في اتخاذ القرار.

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List of Abbreviations

B

(BIM) …………………………………….….Building Information Management

C

(CAD) …………………………………………….…... Computer Aided Drafting

(CIM) ……………………………………………………City Information Model

(CRP) ……………………………………....…..Close Range Photogrammetry

D

(DEM) …………………………………….…………… Digital Elevation Model

(DTM) ……………………………………….………...…. Digital Terrain Model

G

(GIS) ………………………………………………Geographic Information System

L

(LOD) …………………………….…………………………...Level Of Detail

T

(2D) …………………………………………………………...Tow Dimension

(3D) …………………………………………………………...Tree Dimension

W

(WGS) …………………………………….………… World Geodetic System

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

1.2 THE RESEARCH PROBLEM

1.3 RESEARCH OBJECTIVES

1.4 RESEARCH SIGNIFICANCE

1-1 INTRODUCTION

In order to be in line with the great urban progress in the country and permanent renewal of buildings and to go along with the progress of the society and building requirements of existing infrastructures such as universities, hospitals and airports, there is a continuous challenge to plan and add new buildings for public services.

One example is Khartoum Airport, for which passengers are suffering from difficulties of knowing places of halls (departure hall, arrival hall) and how to reach it, especially the new passengers.They are wasting their time in asking a way to reach a particular place inside the airport - this could have a negative effect on the traveling time or the completion of the registration procedure on time. Therefore, any plan and project to assist the airport administration to develop the airport and the provision of passenger's comfort is welcome.

Starting off from that point, different ideas and techniques grew up to make it easier for passengers and guiding them to reach a particular place. In this dissertation, three-dimensional visualization with texture mapping is applied to make the true simulation of reality. On the other hand, GIS environments offer a flexible interactive system for providing the best visual interpretation, planning and decision making process.

One of the most important concepts to be knowledgeable of when planning the development of 3D urban maps is that very different types of maps can be designed and created, often dependent on the intended application requirements and how they will be utilized. Some 3D maps and the associated building models are no more than photorealistic images of buildings within a geographic area and are, therefore, limited to providing users with the ability to picture how a specific section of a city looks. This can be great for a handful of simple visualization applications but is inadequate for performing many types of 3D spatial analysis. Another possibility is the creation of robust 3D building models, which may not be as visually attractive as the photo-realistic variety but have the ability to be strongly attributed, enabling a variety of GIS analytics to be performed.

The 3D urban map and associated building models are enabling the convergence of several established disciplines, including engineering computer-aided drafting (CAD), architectural building information management (BIM), and GIS. A single 3D urban map can now contain detailed building specifications, representations of the physical and functional characteristics of a facility, all tied to a 3D geographic location.

This collective urban map, if fully built and attributed, enables a high degree of understanding of the complete urban environment and facilitates an enhanced ability to plan and manage events while providing solid decision making. However, even if partially complete, 3D maps with key attributes enable significant advances over traditional 2D applications. This research will provide some background on various types of 3D urban mapping, explore several different approaches to creating a 3D urban map, and examine a number of potential applications.

(1-A) THE HISTORY OF GIS DATA

The primary source of the majority of the vector data found in today's GIS databases is imagery, which was used primarily as a backdrop for digitizing. Whether captured from aerial photography or possibly scenes taken from satellites, layers such as building footprints, roads, and terrain were extracted and the imagery often discarded. The result has been a 2D flat representation of geospatial objects, which, although providing a wealth of information, falls short of the rich, 3D perspective more closely matching reality. However, recent technological advances have greatly improved the capability to efficiently extract 3D data from imagery, providing a new source for constructing building models or accurately determining the terrain. These improvements, often referred to as 3D intelligent images, are propelling advances in 3D GIS mapping and driving significant changes throughout the industry.

(1-B) THE 3D MAPPING LANDSCAPE

As is so often the case with emerging technologies, several different techniques have been developed and deployed to create and represent an urban landscape in three dimensions. Some methods can quickly construct photo-realistic buildings but have limited use due to their lack of spatial accuracy or detail. Other approaches rely on accurately constructing each building model individually, which can often make sense when representing a city's importance, but this methodology becomes nearly impossible to implement if the goal is to build out a city of 20,000 or more structures. A third alternative often relies on high-resolution remote-sensing data, such as imagery, to define each building's height, volume, and location and often some automation to make the creation of large cities realistic and possible.

To better understand the similarities and differences between the various approaches to 3D urban mapping, it is helpful to review some of the differences between an aerial photograph and a traditional 2D cartographic map. While the aerial photograph is a true picture and may be quite beautiful and realistic looking, it is only possible for the photograph to convey a limited amount of information. The cartographic map, on the other hand, which although somewhat cartoonish looking and not necessarily realistic in many aspects, can be designed to communicate a considerable amount of useful information such as road names, zoning, or cultural boundaries such as city limits (see figure 1.1)

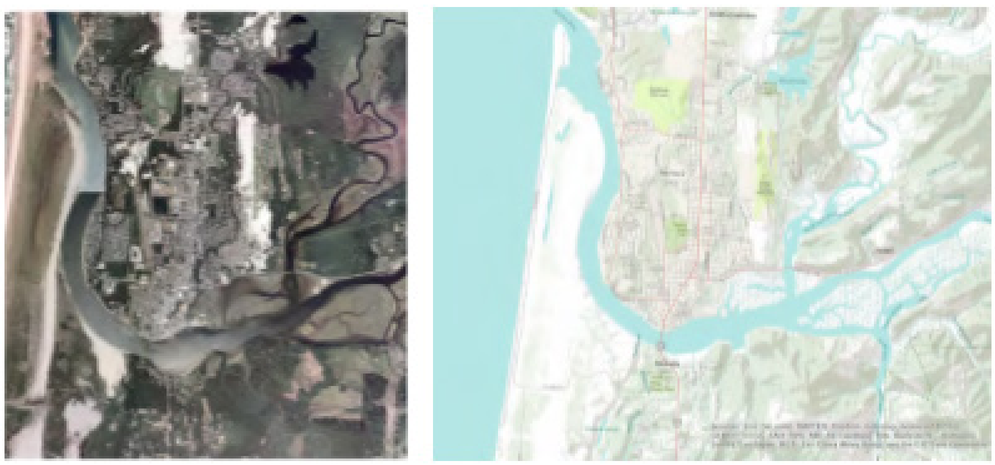


Figure 1.1: Example of Aerial Photography and a Cartographic Map

Similar challenges exist today in the world of 3D urban mapping. Some building models in 3D urban maps are no more than pictures overlaid onto a mesh frame, and although they can be quite remarkable to view, applications for these types of 3D buildings tend to be limited to simple visualization and human interpretation. Another approach to 3D urban maps is to use procedural building models, which are a cartographic product and function more like traditional maps and may even be cartoonish in appearance. However, they are created with the goal of communicating information and have the significant advantage of not only providing clean visualization, but they also enable query and analysis allowing the use of all building-specific GIS data (see figure 1.2).

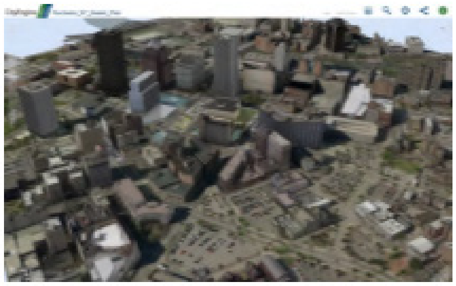
 

Figure 1.2: this graph shows picturesque 3D building versus cartographic 3D building model

(1-C) DATA SOURCES FOR 3D URBAN MAPPING

Diverse approaches exist for constructing 3D urban maps and the associated building models. Data sources can include manually entered architectural specifications, building component libraries, information from various types of remote sensing, and, very often, 2D GIS databases. Depending on the type and quality of the desired 3D urban map, a combination of data sources is usually necessary to develop the map in an efficient, timely, and cost-effective manner.

The digital terrain model (DTM), sometimes referred to as the bare earth, is an important element of any 3D urban map as it is this dataset that provides information on the map's topography and is the base layer on which all other objects, such as roads or buildingmodels, are placed. Airborne lidar data is now commonly utilized to create a high-quality DTM, in part due to its ability to capture large areas with absolute accuracy. Aerial photography is also used for DTM production, as has been done for decades.

Aerial/Satellite photography (nadir and oblique) and/or Lidar are often the primary sources for creating building models. Various methodologies are currently used to extract the desired geographic information, including the ability to create a building's footprint, outline, and the shape of the roof. Building attribute information, such as height, volume, or the slope and aspect of the roof, provides feature augmentation and is often simple and logical to produce. Building models created from remotely sensed data are often accurate and informative, and this approach can often be at least partially automated, which can be very important if the project requires a significant number of buildings to be developed. Software tools can be acquired to create building models from remotely sensed data for a 3D urban map, and numerous vendors, such as CyberCity3D (www.cybercity3d.com/) and Eagle View (www.eagleview.com), provide services for those seeking to have the building models created for them.

In contrast, Trimble Corporation's Sketch Up (www.sketchup.com/) software is one example of a powerful tool designed to enable users to manually create building models with a very high degree of detail and accuracy. Since most cities contain a small number of "special" buildings with historic value or unique architecture, this approach works well for these types of structures. However, manually creating detailed buildings can be extremely time-consuming and may have no controls or standards regarding metadata.

A common source of data that is being increasingly leveraged to construct building models for 3D urban maps is the use of existing "libraries" of features such as building facade textures, windows, and roofs. In addition, libraries now exist for many other features often contained within a 3D urban map, including road networks, vegetation (trees, shrubs), street signage, and street furniture.

One of the most likely sources of quality data that can be used for constructing a 3D urban map is the information contained in existing GIS databases. Features such as building footprints and the number of floors per building can be leveraged to accurately extrude 3D buildings, and parcel data, zoning, and street and sidewalk information provide attribution for future analysis. In addition, a wide variety of assets such as street signs, park benches, or trees can quickly be leveraged resulting in considerable detail in the newly created 3D urban map.

(1-D) CREATING MODELS

Before deciding how to construct the building models for the 3D urban map, several questions need to be answered to ensure the resultant map will be capable of serving the desired functions. The following should be considered:

■ Geographic area? Does your urban map encompass a relatively small or large area, and approximately how many buildings are contained within this

area? What is possible, desirable, and feasible for a small area might quickly become unrealistic or impossible for a larger, more densely constructed area.
■ Map scale? The answer to this question will impact the level of detail necessary for the building models, where in the past a global or landscape scale was adequate, modern requirements demand city or campus scales.
■ Required accuracies? What is important regarding the accuracy of building locations, size, and appearance? More does not always translate into better.
■ How will the 3D map be used? Is visualization the primary application, or will spatial analysis be required? Knowing the answer to this question before you begin construction will likely guide many of your decisions throughout the build-out process and likely influence if a photo-realistic or cartographic approach might make the most sense.
■ Future growth plans? Ideally, any project to construct a 3D urban map should consider growth and maintainability—growth and change within the city itself and increased requirements and applications that may not be required or feasible today (see figure 1.3).

Fig. 1.3: there are different levels of 3D visualization that can be used any type of mapmaking

Once you have determined the key requirements of your urban map, you will need to evaluate the various options for the actual creation of the building models. Numerous trade-offs need to be considered that impact the approach, time, and costs to construct the models. Does the methodology for creating building models need to be scalable, or can each model be handcrafted? Are there regions within the area of coverage where the level of detail (LOD) needs to be significantly greater than the majority of the map, such as the city center or a university campusor airport? Another decision to consider is whether it is desired for the facades of the buildings to be constructed from actual imagery to most accurately represent reality and if it is expected to eliminate foreground objects, such as parked cars, trees, or pedestrians, or if a representative facade obtained from a library and applied to numerous buildings is adequate for the map. If the latter is the case, considerable time and expense can be saved creating the building models. Also, keep in mind that it is not uncommon for several different approaches to be used to create the building models in an urban map.

The next consideration is whether the sponsoring organization has the expertise and resources to build its own 3D urban map and building models using available products or if outsourcing the project to a service provider might be desirable. Depending on the size of the project's geographic area and/or the number of buildings to be modeled and their required LOD, various options exist.
The one option might be to utilize the ArcGIS® platform, if possible.

(1-E) Building or Buying Models

If an organization chooses to create its own building models, software is now available to facilitate the workflow. If a significant number of building models need to be constructed, leveraging automation will likely be critical. The approach and selection of the specific software package to use will greatly depend on the LOD desired and, more importantly, the type and quality of the input datasets available. For example, if building footprints and lidar data are obtainable and the majority of the buildings only need to be LOD1, the workflow described in appendix A using the ArcGIS platform can be utilized to quickly extrude all the buildings automatically with a reasonably high degree of accuracy. If greater building detail (LOD2 or LOD3) is desired for some or all models, the ArcGIS extensions and complementary applications developed by Esri partners might be good options.

(1-F) Storing Building Models

Equally important when attempting to understand 3D urban mapping is to obtain an appreciation for the various ways in which the map and associated models can be stored and maintained. An option is to store the information in the KML format. This solution provides robust options for display and visualization and is commonly used when sharing maps and models outside an organization. Other options available for storing building model information provide more robust and defined data structures and are generally referred to as common information models, which are used to "catalog" all pertinent building information. Features such as a building's location, footprint, height, number of floors, windows, roof characteristics, and/or type of building facade are often included.

Two common formats include CityGML (www.citygml.org/) by the Open Geospatial Consortium, Inc., and Esri's recently released City Information Model, or 3D-CIM. Several key differences exist between these two formats, and while CityGML has a solid structural base because it was originally designed as a transfer format, it is hard to efficiently search for information such as, how many rooms does the building have? especially in cases where there are many buildings included. 3D-CIM, on the other hand, is an extensible data structure schema designed for data management and analysis and allows the inclusion of whatever types of data fields that make sense for the building model. It can even include information that is compatible with existing GIS databases.

(1-G) APPLICATIONS FOR 3D URBAN MAPS

Opportunities to utilize 3D urban mapping are increasing rapidly as more cities transition from 2D to 3D GIS. Fortunately, if the map is constructed in such a way that new data can be added as it becomes available, the usefulness of the map will continue to increase as additional applications and workflows are developed. Today's most common applications can be categorized into simulation, urban planning, transportation, real estate, and census.

One of the common early uses of 3D urban mapping is simulation for flood modeling, which has grown in importance since Hurricane Katrina in 2005. When building, models are combined with accurate terrain data (DTM), simulations can be created that accurately identify areas of risk based on a variety of what-if scenarios. Modeling the environment in 3D can aid in such things as determining the impact of storm surge and assisting in the siting of evacuation routes and centers. Mapping of critical infrastructure, such as electrical distribution, can also be done more accurately in 3D, as well as contingency planning, determining requirements for continuity of operations, and recovery efforts.
while a graph is helpful for understanding the number of buildings that could sustain water damage during a flood it only tells part of the story (see figure 1.4 A,B)

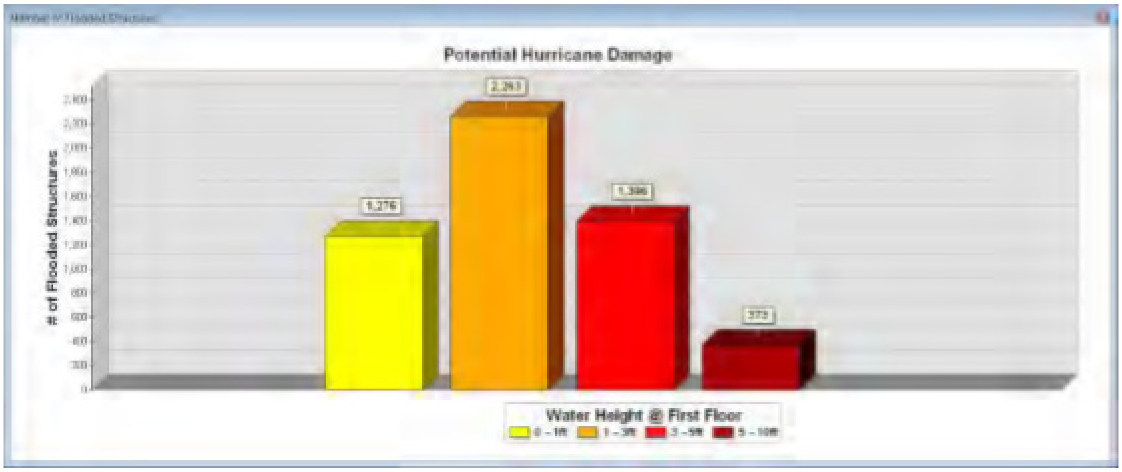


Fig. 1.4, A: 3D urban mapping is simulation for flood modeling

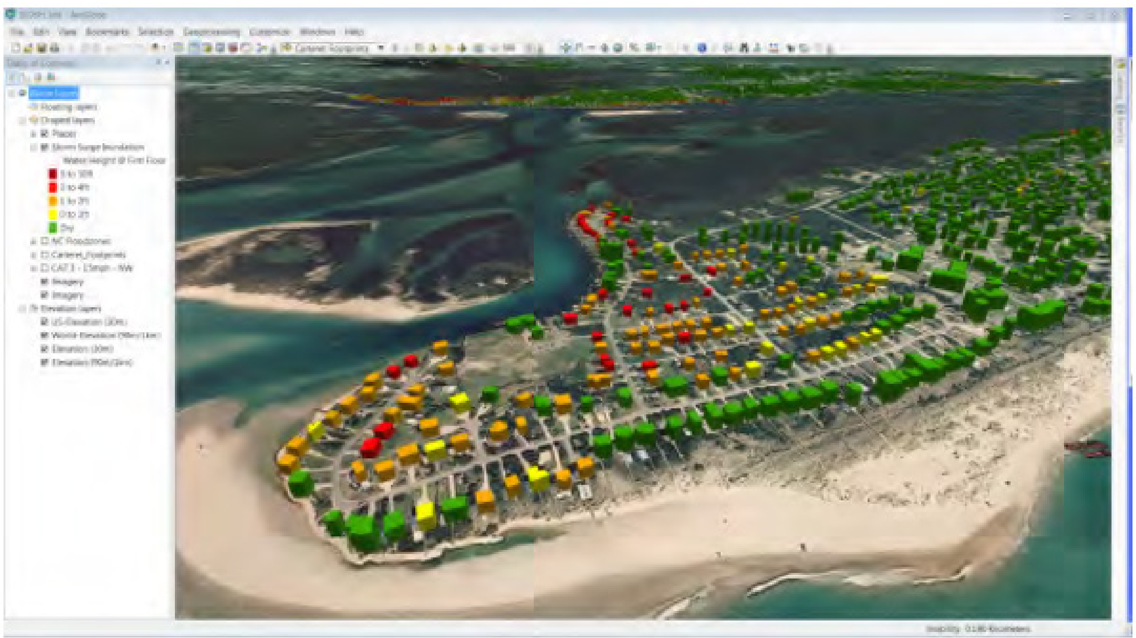


Fig.: 1.4, B: 3D urban mapping is simulation for flood modeling

Urban planners have begun to regularly rely on 3D urban maps to support a wide variety of everyday decision making tasks. When the construction of a new structure is proposed, it is now possible to assess the visibility impacts of the new building on the surrounding area. Better understanding the effects of shadow and potential sun exposure to nearby buildings can help determine how best to build a "green" building. And as highlighted in a case study from the City and County of Honolulu below, identifying a single building or group of building's potential for solar power use has now become feasible and practical. Real estate organizations are also beginning to leverage the information contained

1-2 THE RESEARCH PROBLEM

This project will provide answers to the following questions showing the research problem:

- What is the effect of designing a system or application representing the geographical locations in a three-dimensional representation for the buildings of Khartoum International Airport?
- What are the goals and the importance of designing a system or applications to represent the geographical areas in three-dimensional modeling?
- What is the influence degree and contribution of applying the system on the passengers in Khartoum International Airport?
- What are the techniques to be used in designing three-dimensional systems?
- What is the importance of using the selected technology in the proposed system?
- What is the scope of applying the system?
- What are the obstacles and difficulties that hinder the system working smart?

1-3 RESEARCH OBJECTIVES

- The main purpose of this research is to understand the benefits of utilizing interactive, three- dimensional (3D) visualization by designing a 3D model for Khartoum International Airport to assist the passengers,the airport administrationand visitors when they need to reach any place inside the Airport.
- Restructuring of the airport
- Provides information about all resources inside the Airport.

1-4Research Significance:

Represented in Research Objectives

CHAPTER 2

RELATED WORK AND LITERATURE REVIEW

2.1 THEORETICAL FRAMEWORK.

2.2 LITERATURE REVIEW.

2.3 SYSTEM DESCRIPTION.

2.1 THEORETICAL FRAMEWORK

In the following we use methods of computer graphics, Geographic Information Systems and photogrammetry to solve the problem of constructing Virtual Reality 3D models and to convert them into GIS objects allowing for spatial analyses, such as short path analysis, buffering and 3D spatial analyses Therefore, the strength of these three fields is presented first.

2.1.1 COMPUTER GRAPHICS

The term computer graphics has been used a broad sense to describe "almost everything on computers that is not text.Typically, the term computer graphics refers to several different things:

- the representation and manipulation of image data by a computer
- the various technologies used to create and manipulate images
- the sub-field of computer science which studies methods for digitally synthesizing and manipulating visual content, see study of computer graphics

Many powerful tools have been developed to visualize data. Computer generated imagery can be categorized into several different types: two dimensional (2D), three dimensional (3D), and animated graphics. As technology has improved, 3D computer graphics have become more common, but 2D computer graphics are still widely used. Computer graphics has emerged as a sub-field of computer science, which studies methods for digitally synthesizing and manipulating visual content. Over the past decade, other specialized fields have been developed like information visualization, and scientific visualization more concerned with "the visualization of three dimensional phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component.

2.1.2 GEOGRAPHIC INFORMATION SYSTEMS (GIS)

GIS Definition

GIS is a technological field that incorporates geographical features with tabular data in order to map, analyze, and assess real-world problems.
And also GIS is a computer based system that provides the following four sets of capabilities to handle geo-references and data.

Uses of GIS

There are numerous ways in which this technology can be used. The most common ones are:

1. Management of resources
2. Investigations of the earth's surface that is scientific in nature
3. Archeological uses
4. Planning of locations and management of assets
5. Urban & regional planning
6. Criminology matters
7. An Impact assessment of the environment
8. The assessment and eventual development of infrastructure
9. Studies of the demographics of an area plus its population
10. Analysis with regards to engineering

Data

Data is the core of any GIS. There are two primary types of data that are used in GIS: vector and raster data. A geodatabase is a database that is in some way referenced to locations on the earth (see fig. 2.1). Geodatabases are grouped into two different types: vector and raster. Vector data is spatial data represented as points, lines and polygons. Raster data is cell-based data such as aerial imagery and digital elevation models. Coupled with this data is usually data known as attribute data. Attribute data generally defined as additional information about each spatial feature housed in tabular format. Documentation of GIS datasets is known as metadata. Metadata contains such information as the coordinate system, when the data was created, when it was last updated, who created it and how to contact them and definitions for any of the code attribute data.

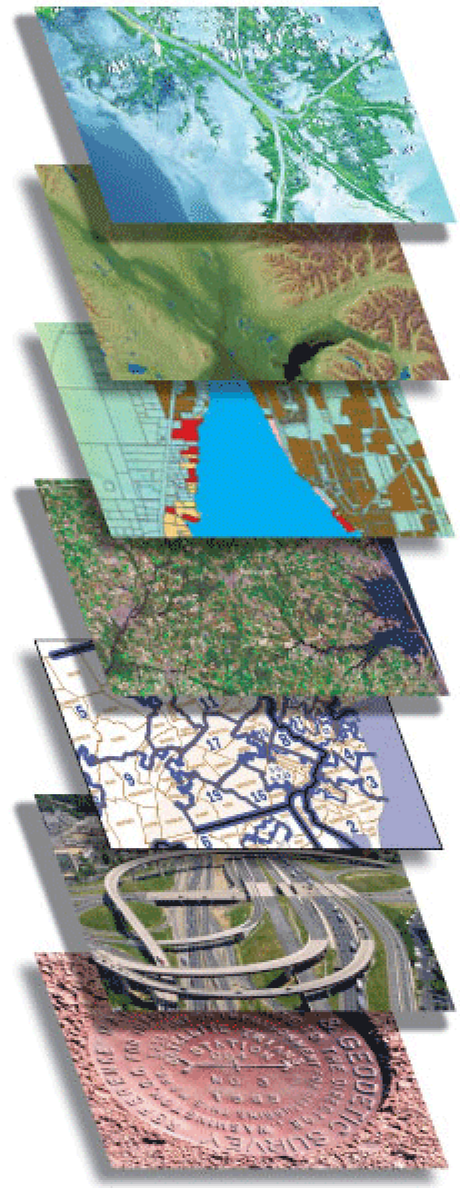


FIG. 2.1: GIS DATA LAYERS. SOURCE: FCDC

2.1.3 PHOTOGRAMMETRY

Photogrammetry is the science of making measurements from photographs. The output of photogrammetry is typically a map, drawing, measurement, or a 3D model of some real-world object or scene. Many of the maps we use today are created with photogrammetry and photographs taken from aircrafts.

Types of Photogrammetry

Photogrammetry can be classified a number of ways but one standard method is to split the field based on camera location during photography. On this basis, we have Aerial Photogrammetry, and Close-Range Photogrammetry.

In Aerial Photogrammetry the camera is mounted in an aircraft and is usually pointed vertically towards the ground. Multiple overlapping photos of the ground are taken as the aircraft flies along a flight path. These photos are processed manually in a stereo-plotter (an instrument that lets an operator see two photos at once in a stereo view) or semi- and automatically (Bundle Block Adjustment and Dense Image Matching). These photos are also used in automated processing for Digital Elevation Model (DEM) creation.

In Close-range Photogrammetry the camera is close to the subject and is typically hand-held or on a tripod (but can be on a vehicle too). Usually this type of photogrammetry is non-topographic - that is, the output is not topographic products like terrain models or topographic maps, but instead drawings, 3D models, measurements and point clouds. Everyday cameras are used to model and measure buildings, engineering structures, forensic and accident scenes, mines, earth-works, stock-piles, archaeological artifacts, film sets, etc. This type of photogrammetry (CRP for short) is also sometimes called Image-Based Modeling.

Digital photogrammetry is a well-established technique for acquiring dense 3D geometric information for real-world objects from stereoscopic image overlap and has been shown to have extensive applications in a variety of fields.

Aerial photogrammetry refers to the collection and processing of imagery captured from an aerial or orbital vehicle. Close-Range photogrammetry (CRP) refers to the collection of photography from the ground or some lesser distance than traditional aerial photogrammetry and is becoming increasing popular and accessible due to new, easy to use software and digital cameras. Non-metric, off-the-shelf digital cameras can be used along with relatively inexpensive, or in some cases free, open-source software, to extract and process highly accurate and detailed 3D models of real-world objects (see fig. 2.2 & 2.3).

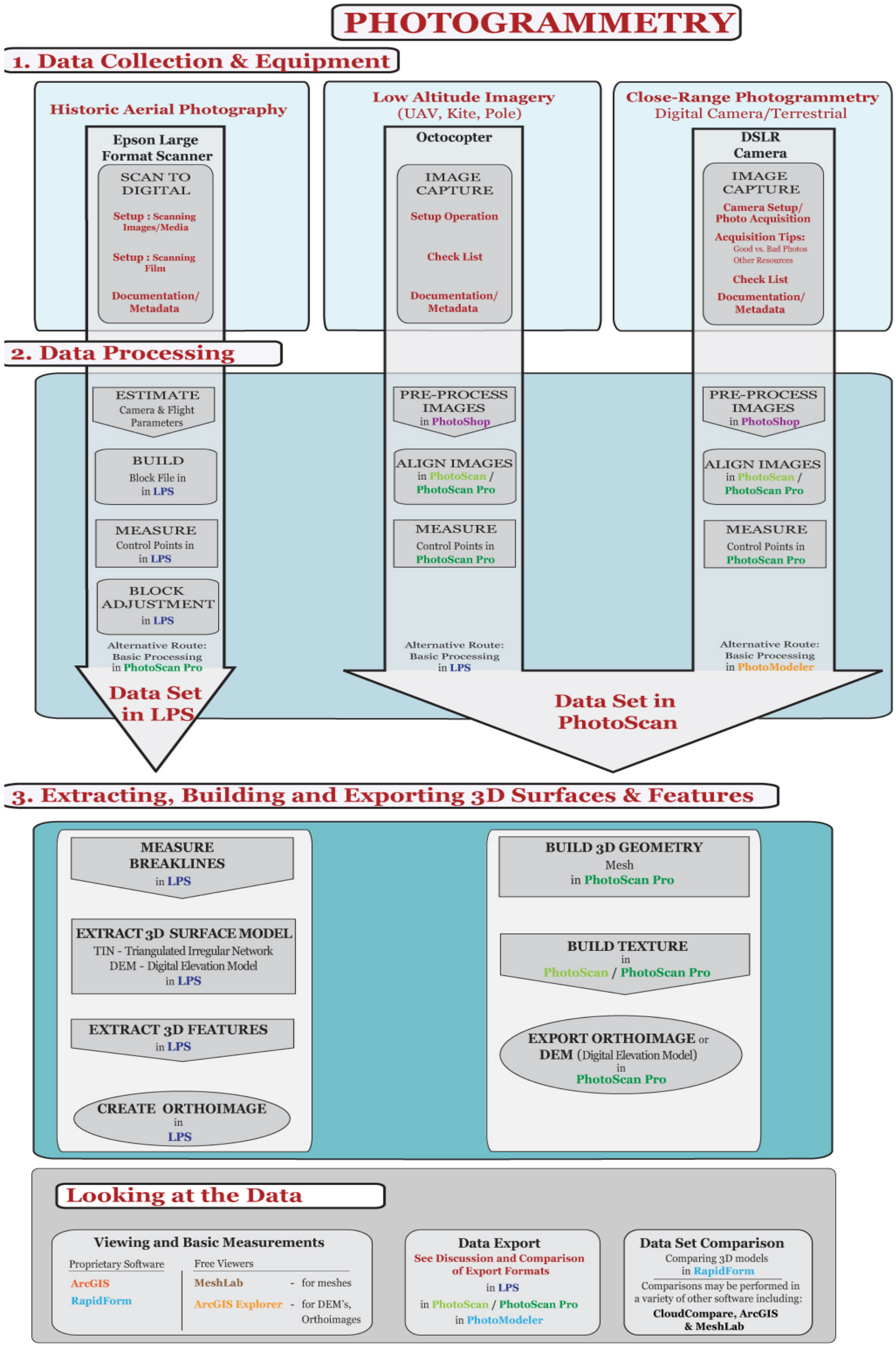


Fig. 2.2: Workflows in photogrammetry

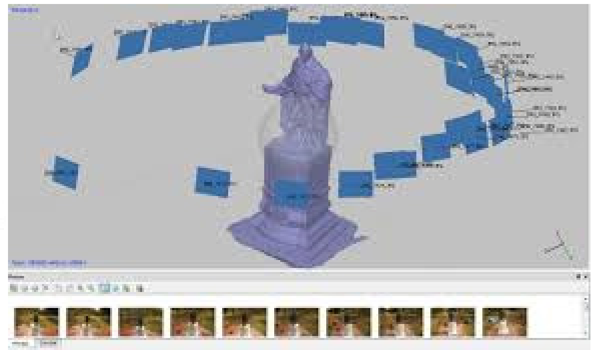


Fig. 2.3: The 3D Mapping process: (a) airborne photogrammetry, and (b) close-range Photogrammetry

Techniques for 3D Mapping

3D Mapping is used for:

1. Robots operate in the three-dimensional world
2. Three-dimensional maps, which support

• Object recognition.
• More accurate path planning
• More reliable localization and data association.
• Navigation on uneven terrain.

3D computer graphics

3D computer graphics (in contrast to 1TU2D computer graphicsU1T) are graphics that use a three-dimensional representation of geometric data (often 1TUCartesianU1T) that is stored in the computer for the purposes of performing calculations and rendering 2D images. Such images may be stored for viewing later or displayed in 1TUreal-timeU1T. [3]

Almost all 3D models can be divided into two categories.

• Solid - These models define the volume of the object they represent (like a rock). These are more realistic, but more difficult to build. Solid models are mostly used for nonvisual simulations such as medical and engineering simulations, for CAD and specialized visual applications such as 1TUray tracingU1T and 1TUconstructive solid geometryU1T.

• Shell/boundary - these models represent the surface, e.g. the boundary of the object, and is not a volume (like an infinitesimally thin eggshell). These are easier to work with than solid models. Almost all visual models used in games and films are shell models.

3D modeling software

3D modeling software is a class of 3D computer graphics software used to produce 3D models. Individual programs of this class are called modeling applications or modelers.

3D models represent a 3D object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or by scanning.

Modeling process

1. **Polygonal modeling**- Points in 3D space, called vertices, are connected by line segments to form a polygonal mesh. The vast majority of 3D models today are built as textured polygonal models, because they are flexible and because computers can render them so quickly. However, polygons are planar and can only approximate curved surfaces using many polygons.

2. **Curve modeling** - Surfaces are defined by curves, which are influenced by weighted control points. The curve follows (but does not necessarily interpolate) the points. Increasing the weight for a point will pull the curve closer to that point. Curve types include non-uniform rational B-spline (NURBS), splines, patches and geometric primitives.

3. **Digital sculpting** - There are currently 3 types of digital sculpting: Displacement, which is the most widely used among applications at this moment, volumetric and dynamic tessellation.

2-2LITERATURE REVIEW:

Through research on studies on the application of the concepts and techniques of 3D modeling quite a number of publications have been produced. In the following we will restrict ourselves to review three papers:

Definition of prior study:

- **Title of Study:**

Hawaiian Islands in 3D

- **Name of researcher**

An Esri® White Paper

- **Study objectives**

The State of Hawaii, Office of Information Management and Technology, is now offering 3D GIS building models covering more than 25 square kilometers and consisting of 19,500 measured buildings of Honolulu as part of its Open Data Program. These highly accurate building models were created from stereo aerial imagery by Cyber City 3D (www.cybercity3d.com/) as part of the Hawaii Office of Planning's efforts to gather, analyze, and provide information to the governor to assist in the overall analysis and formulation of state policies and strategies. To help the state plan for its future sustainability, the 3D building models have been used to show the potential for solar renewable energy for buildings, with solar exposure values calculated on actual roof areas and orientation of the roofs to the north.

- **Title of Study:**

Texture Mapping and Implementation Aspects for 3D GIS Applications

- **Name of researcher**

Nedal Al-Hanbali

- **Study objectives**

3D modeling of Al Hussein Public Parks

The main objective of 3d modeling and texture mapping is to build suitable procedure for documentation of cultural heritage objects and thus to serve as a tool to make information accessible for documentary and research tourism.

Applications for any interested persons, who can investigate the object without going to the site. The result of the documentation has to include not only the graphical knowledge, but also some no graphical information such as objects' history, conservation status and owners

- **Title of Study:**

GIS Applications for Building 3D Campus, Utilities and Implementation Mapping Aspects for University Planning Purposes.

- **Name of researcher:**

A. Al-Rawabdeh, N. Al-Ansari, H.Attya1 and S.Knutsson**.**

- **Study objectives:**

A real 3D GIS model for the campus of the Al al-Bayt University. The following study built a 3D GIS map and all utility information for Al al-Bayt University campus as an example. The primary objective is to improve data management (e.g. Maps, plans, usage of facilities and services) and to develop methods using 3D spatial analysis for specific applications at the university.

2.2.2 **Own comments on previous studies**

The previous studies contributed to an examination to use current off-the-shelf software technology to build geometry and texture for 3D GIS models using several techniques for various applications. This research aims to take advantage of the proposed recommendations, including the possibility of applying the regulations on the 3D mapping systems using photogrammetry and viewing real world models over PC's desktop environment.

2-3 SYSTEM DESCRIPTION

2.3.1 Current System

Khartoum International Airport, Khartoum consists of a number of offices and halls: the presidential offices, halls, and offices of particular interests such as the departures hall and arrival hall. The current system relies on labeling and signs with names of faculties and departments and the names of the halls and offices of every building. For passengers during traveling time or arriving time the Khartoum International Airport offers some brochures and banners greeting for each building and some information about the departments and halls with pictures. Placed signs indicate the proceduressteps. For visitors there is a person appointed to help them as a guide.

2.3.2 Current System Problems

1. The passenger have no idea about the airport and procedures before travelling, unless coming to the airport.
2. Labels or Signs of buildings are not obvious small.
3. Some privacy places for males/females are not cleared as well as prayers places.
4. Passengers, especially passengers who are traveling for the first time have to ask every time when they want to reach a particular place during the journey.
5. Delaying and loosing time and efforts asking about locations and Procedures.
6. Wasting time for asking that means lost our flight and ticket .

2.3.3 Proposed System Description

The main objective of 3D modeling and texture mapping is to build suitable procedures for Khartoum International Airport buildings and thus to serve as tools to make information accessible for passengers and visitors, who can investigate the airport without going to the site. The importance of airport planning focuses on offering 3D real world visualization for Khartoum International Airport main buildings with its semantic information. In addition, the proposed system will be accessible from desktops and smartphones to take advantage of the virtual visualization anytime.

2.3.4 Scope of system

The proposed system offers a 3D model for the Khartoum International Airport and includes the following buildings: Airport Administration, Departure hall, Arrival hall, Domestic hall, Aircraft,Luggage store, also mosques andetc... The system offers 3D visualization for buildings as well and provides information using desktop and tablet computers.

Chapter 3

Methodology and Research Planning

3.1Overview

3.2 Research community.

3.3 Methodology and Research Planning.

3.4 Selected Methodology and techniques

3-1 Overview

This chapter contains three main headlines, the first about the community of research; the second is methodology and research planning, and the third one is selected methodology and techniques.

3-2 Research Community

An airport represents a complex infrastructure. Especially passengers who are traveling for the first time and visitors because they have a hard time to orientate themselves and finding places and do not know procedures. The Khartoum International Airport has different buildings with different halls - most of these buildings are far from each other. Even if there are maps at some points on and within the airport, passengers do not have continuous help to get to their destination. They can try to figure out a way to get to their target on these static maps, but as soon as they start walking in the target direction they are without help anymore. So, how is it possible to help freshmen and inexperienced people to orientate them on the airport and how can they be supported using modern tools.

The Airport contains so many building Administration offices, Departure hall, Arrival hall, Domestic hall, Aircraft, Luggage store, Aircraft Maintenance hall and also mosques etc.

3-3 Methodology and Project Planning

The objective of this research was to support decisions for the development of virtual Airport models by presenting a structured overview of 3D GIS analyses that are likely to be applied in 3D modelling.

The research methodology and project planning will be done in the following steps, by using ARCGIS applications: data acquisition, generation of a 3D model, visualization of the 3D model. In the following the implementation steps required to build a true reality 3D GIS model of Khartoum International Airport with texture mapping are given.

- Data Modeling.
- Data Measurements, Processing and Preparation
- Building of 3D models.
- Build a 3D GIS model with all relational spatial data bases.
- Texture Mapping.

3.3.1 Data Modeling:

-Data collection of all available geospatial databases and attribute data no matter it is

- Images captured by scanning buildings for dense image matching.
- Point cloud files (Las data format).
- Files available from point clouds for the 3D model construction.
- Attribute database and documentations related to the Airportinformation.

GIS Data Modeling: This is an important step to define all required geospatial databases including vector and raster classes and their relationships based on the defined objectives of the project. This will draft what is required and also missing to build the desired GIS data model.

3.3.2 Data Measurements, Processing and Preparation: To build the required 3D GIS information system.

-Data measurements and capturing: In this process some important data measurements are given:

- Dense images of the area of interest using a high precision camera.
- Stereo images of objects to build 3D models,
- Photos of required texture to be used as filters, later on to put texture to 3D models.

- Data Processing and Preparations: In this process, the important processing steps are as follows:

- Build point clouds for the area of interest (using AgiSoftPhotoScan).
- Build 3D view of the point clouds (Autodesk 3DMAX and Trimble SketchUp are used).
- Edit captured photos and add texture (MS Paint is used).
- According to the GIS data-model, build 2D layers and also add their attribute data (Esri ArcMap is used).
- Build relational databases within the GIS data model layers (Esri ArcMap and EsriArcEditor are used).

3.3.3 Build 3D Model:

Based on required details and available spatial data and also according to the GIS data model design all the needed features are selected. In the following are the important implemented cases: [7]

Case I Simple 3D shape geometry: In this case the 2D layer was built and the height dimension was determined either by direct survey measurements or taken from CAD drawings. The 3D model can be built directly in the 3D GIS software environment. The shape appears like 3D block shapes (EsriArcScene software is used).

Case II 3D CAD Model is available: In this case, the dimensions have to be verified by scaling it with the built 2D layer and also via survey measurements. The final 3D model is then verified and georeferenced to its exact position on a map (Autodesk AutoCAD and Trimble SketchUp software's are used).

Case III Only 2D layer is available: In this case close range photogrammetry is used to build a 3D wire mesh of the required object(s) using the captured stereo imagery during the data capturing step (AgiSoftPhotoScan and Photomodeler software's are used).

Case IV some parts are available in 2D and others in 3D: Combination of case II and III is used, but it is very important to use a consistent reference system to merge all 3D objects into one object (Trimble SketchUp software works well in this case).

3.3.4 Build a 3D GIS model with all relational spatial data base

that corresponds to the 3D model. There are several techniques to insert the built-up 3D models from step 3 within the 3D GIS environment as follows: [7]

- The 3D GIS environment in our case is the ArcScene environment of the ArcGIS software. The datum for providing a reference base-height for any inserted point, 2D or 3D objects is chosen.

• **Case I Simple 3D shape geometry**: In this case ArcScene build the 3D model directly using the 2D vector layer with the added height information as part of the layer attribute for each feature in the layer, or added directly as a constant height for all features in the layer. A DTM is also specified as the base-height for all layers.

• **Case II 3D CAD Model is available:** In this case, if the CAD software has the capability to export the 3D model file into 3D shape file, it then can be inserted directly into the ArcScene environment. Quite often the file can be imported into SketchUp software, where it will be exported into the proper format for ArcScene. It is important to note that complex 3D models should be split as much as possible to smaller objects in order to be able to export it easily into the environment using the geodatabase format. Our practice found that the best scenario is to use SketchUp software. You can better control your splitted objects since the export formats are geodatabase standards. Also, it is important to georeference the model to its exact position in ArcScene before exporting it.

• **Case III Only 2D layer is available:** In this case close range photogrammetry such as PhotoModeler or other photogrammetry software such as SOCET SET or Z/I can export the 3D model to 3D CAD model or shape file. Our recommendation is to convert the models to CAD format and then exporting them to SketchUp software and repeat the same as described above.

• **Case IV some parts are available in 2D and others in 3D:** A Combination of case II and III is used, but it is very important to use a consistent reference system to merge all 3D into one object (SketchUp software works well in this case).

3.3.5 Texture Mapping:

Appending to all facets of the 3D features the true texture is very essential to simulate reality and thus provide the user/planner with a true scene, that can help in making better decisions. The following are the options and scenarios one can follow: [7]

- Use the Orthophoto with added DTM as a base-height to provide true texture of the earth and ground surface for the area of interest.

-Append/stitch texture to build up 3D models using the following options:

• **Orthophoto Accurate Texture Mapping:** One needs to build Orthophotos of all the faces of the objects. Use these images as filters to append/stitch these to the 3D CAD model surfaces using Sketch up or 3D MAX software's.

• **Direct photo Texture Mapping**: It is important when capturing the photos for the model surfaces to make the line of site of the camera axis as perpendicular as possible to the surface of interest. Then use these photos as filters to append/stitch these to the 3D CAD model surfaces using SketchUp or 3D MAX software.

• In both cases, the best way to export the 3D model with texture is through exporting all models to SketchUp software and then exporting it in a geodatabase format to ArcScene software.

- Export the built up 3D model object with texture as point-symbols. SketchUp software is designed to work perfectly in case of:

• The object is designed to provide general attributes of the whole building for example, if he object is very complex and cannot be exported as true 3D model with texture.

• The objects are standard and are very similar in shape such as villa compounds, To be built using other software's such as SketchUp or 3D Max.[7]

The resultant 3D reality model offers a flexible and interactive visual decision support system for data management. The following sections are the direct implementation results of the above discussed methodology for various applications, that are related to the conducted system.

3.4 Selected methodology and techniques

The suggested methodology is very flexible and can be utilized and implemented for various types of projects and applications, that are becoming essential in the near future. Photogrammetry and Texture mapping is now becoming feasible with low cost and less time consuming using the new capabilities of the below mentioned software's. In this proposed system, several software's will be employed and used in order to complete the required production, which are the following:

a. AgiSoft'sPhotoScan:

- AgiSoftPhotoScan is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from still images. [9]
- It will be used to extract the point clouds by dense image matching of the areas of interest.

b. TrimblesSketchUp Pro (version 2016):

- The platform enables users to create collections of models, including 3D buildings, and share them with fellow modelers around the world. SketchUp, which was a tiny startup when it was bought by Google in 2006, now boasts of millions of active users. [10]
- It will be used to import point clouds in *.las format and exporting 3D models from and to ArcGIS depending to build/complete 3D building models. Finally, it is used for adding the true texture to these models.
- The Undet extension package works well with SketchUp for importing point clouds and exporting 3D models in various file's formats.

c. Esri's ArcGIS 10.1:

- ArcGIS Desktop is comprised of a set of integrated applications, which are accessible from the Start menu of your computer: ArcMap, Arcscene and ArcCatalog. **ArcMap** is the main mapping application which allows you to create maps, query attributes, analyze spatial relationships, and layout final projects. **ArcCatalog** organizes spatial data contained on your computer and various other locations and allows for searching, previewing, and adding data to ArcMap as well as manage metadata and set up address locator services (geocoding). **ArcToolbox** is the third application of ArcGIS Desktop. Although it is not accessible from the Start menu, it is easily accessed and used within ArcMap and ArcCatalog. ArcToolbox contains tools for geoprocessing, data conversion, coordinate systems, projections, and more. [11]
- ArcMap will be used to build 2D GIS layers and data-model, in addition to ArcScene that provides suitable 3D environment

d. Sketchfab:

- Is the leading Internet platform to publish and find 3D and VR content, anywhere online. Moreover, it is a good environment to upload files in almost any 3D format. [12]
- Sketchfap will be used to visualize the 3D model in VR mode by uploading the model to be accessible online

Chapter 4
System Analysis and Design

4.1 OVERVIEW

4.2 SYSTEM REQUIREMENTS

4.3 ANALYSIS AND DESIGN

4.1 Overview

This chapter contains system requirements, subdivided in functional and non-functional requirements and system analysis with design.

4.2 System Requirements

4.2.1 Functional Requirements:

1. The system provides 3D design for Khartoum International Airport.
2. The system aims to provide information about all the Airport buildings.
3. Also its aims to represent all resources within the Airport in a hologram.
4. The system offers real world visualization, helps passengers and administrators viewing the resources inside the Airport and administration buildings.
5. It also supports virtual visualization over desktop platforms to be accessible anytime.
6. The system illustrates locations of the halls (arrival hall, departure hall, domestic) and buildings.
7. It also illustrates locations of landmarks, gates and textured buildings.
8. It even identifies locations of mosques and other places of prayer in the Airport by defining restrooms and private sections for male and female.
9. It illustrates locations of cafeterias.
10. At this point in time trees are not yet involved in the model.

4.2.2 Technical Requirements:

The building geometry (dense point cloud and mesh generation) usually has the largest memory footprint, especially if the model is constructed in medium or high quality.This fact should be carefully taken into account. The processing of the photographs and the 3D model construction comprises the following main system requirements:

Minimal configuration

- Windows XP or later (32 or 64 bit), Mac OS X Snow Leopard or later, Debian/Ubuntu (64 bit).
- Intel Core 2 Duo processor or equivalent.
- 2GB of RAM

Recommended configuration

- Windows XP or later (64 bit), Mac OS X Snow Leopard or later, Debian/Ubuntu (64 bit).
-Intel Core i7 processor.
-12GB of RAM.

The number of photos, that can be processed by PhotoScan depends on the

available RAM and reconstruction parameters used. Assuming that a single photo resolution is of the order of 10 MPixel, 2GB RAM is sufficient to create a model based on 20 to 30 photos.12GB RAM will allow to process up to 200-300 photographs.
In addition capturing photos for objects must be taken panoramically and it is better to use a high precision camera as well as an Xcopter with a camera on board. The resulting 3D model must be available over desktops and various smartphone platforms (Windows, Android, and iOS)

4.2.3 Nonfunctional Requirements

In order to obtain better model visualizations, the system has to achieve the following specified requirements:

1. Performance: The most important requirement is the performance of the system which includes the following:
   - Query and Reporting time: the response time between the mouse action and retrieving object information.
   - Response time: also the time of loading the model, which is subject to the screen refresh times or orientations.
2. Availability: the system needs to be available all the time, for every passengers / visitor over desktop and smartphone platforms.
3. Maintainability: the model also has to be updated due to the ongoing renewal of Airport buildings.

4.3 Analysis and Design

4.3.1 Database Design

As well known, GIS layers are groups of features organized object-wise and are stored in a Shapefile format. In this Research, 2D and 3D layers have been created using Esri's ArcGIS software. The model comprises 2D GIS layers, which contain the geospatial data of the objects. In particular these layers are the building layers.

4.3.2 Database Transactions

- Information retrieval is essentially required, when the users inquire about a particular object by getting a popup message. Thus the data must be well organized.
- The 3D model of the Khartoum International Airport will be visible for each passengers and visitor online for better view and access over desktops (Web browser) and smartphones allowing them to orient the model or retrieve geodata in response of a mouse click.

Chapter 5
Simulations and Results

5.1 INTRODUCTION
5.2 PHOTOGRAMMETRY
5.3 3D MODEL RECONSTRUCTIONS

5.1 Introduction

This chapter contains a full documentation of the main interfaces of the system, which has been ordered according to the implementation using 3D modelling software sequentially. For the photo shooting, a Canon G1X DSLR camera and a smart phone are used (see figure 5.1)

5.2 Photogrammetry

- A 3D model of the main campus is created. An excerpt of an aerial photo from Google Maps has been taken illustrating the region and location of Khartoum International Airport (Figure 5.2).
- The first step of the study was getting the point clouds of the buildings from a collection of overlapping images using Dense Image Matching. To build the required 2D and 3D GIS information system, some data measurements and processing were applied.
- Furthermore, we have to take more images in this research.
- A set of overlapping images have been captured panoramically using CANON camera and a mobile phone camera as illustrated in (figure 5.3, figure 5.4).

Figure 5.1 Canon camera and smart phone

Figure 5.2: An image patch from Google Earth excerpt illustrating the Geographical Location of Khartoum International Airport

Figure 5.3: Several Photos “scanning” the departure hall (outside)

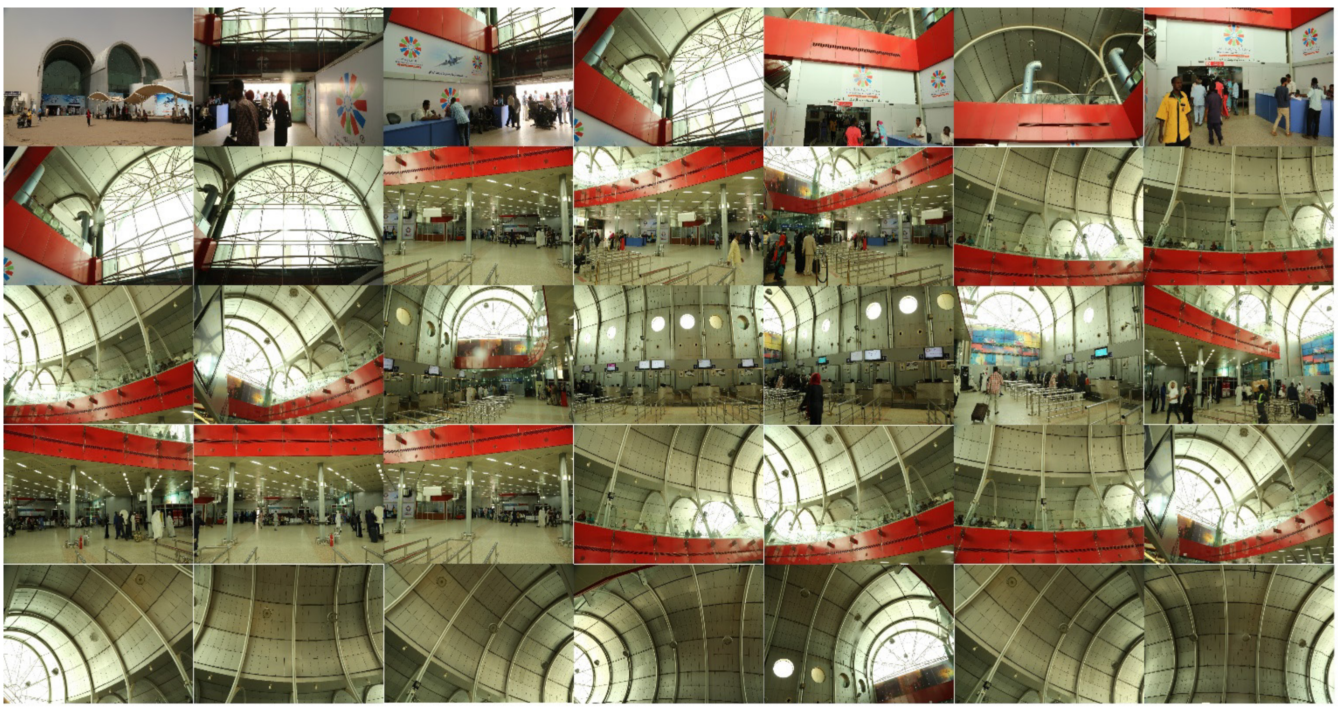


Figure 5.4: Several Photos “scanning” the departure hall (inside)

5.2.1 AgiSoft

- PhotoScanis a software of AgiSoftfor the pose estimation and dense image matching.
- AgisoftPhotoScan is a stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data. (Figure 5.5)

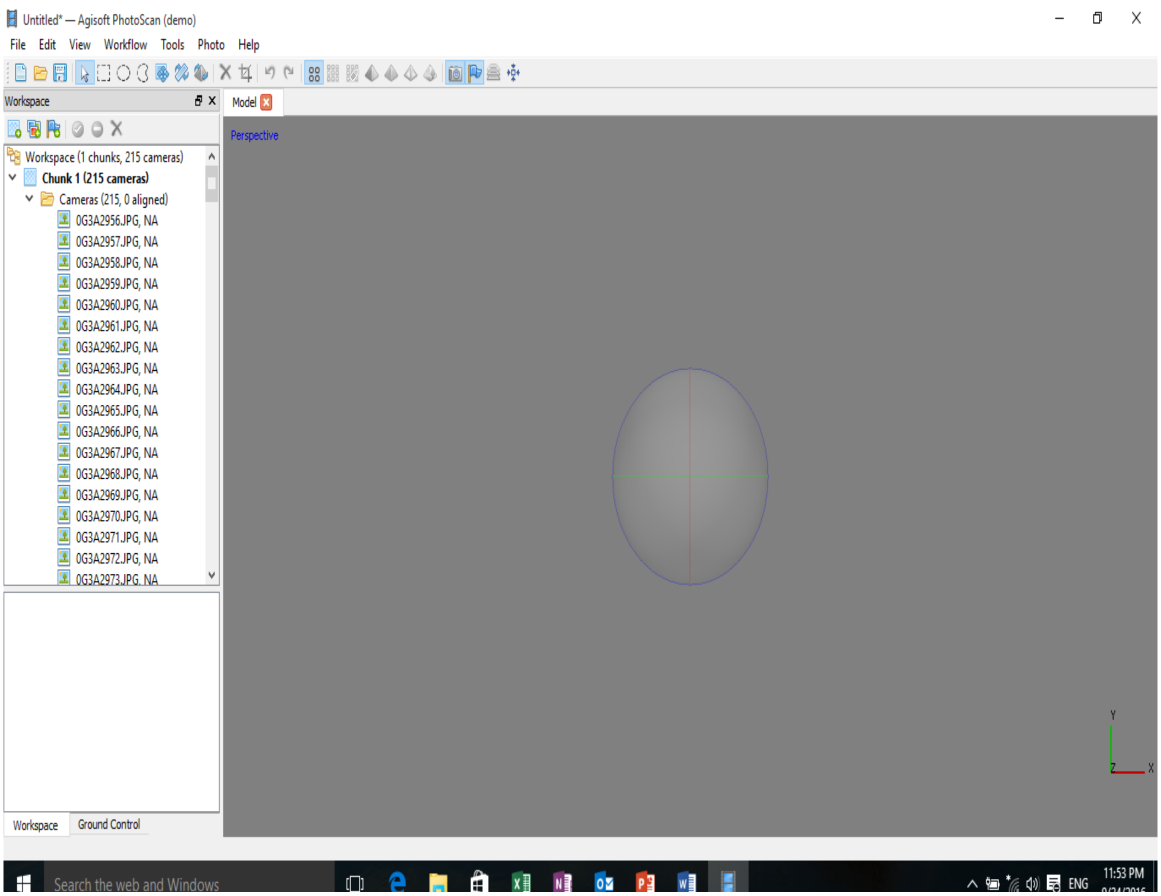


Figure 5.5 Agisoft program

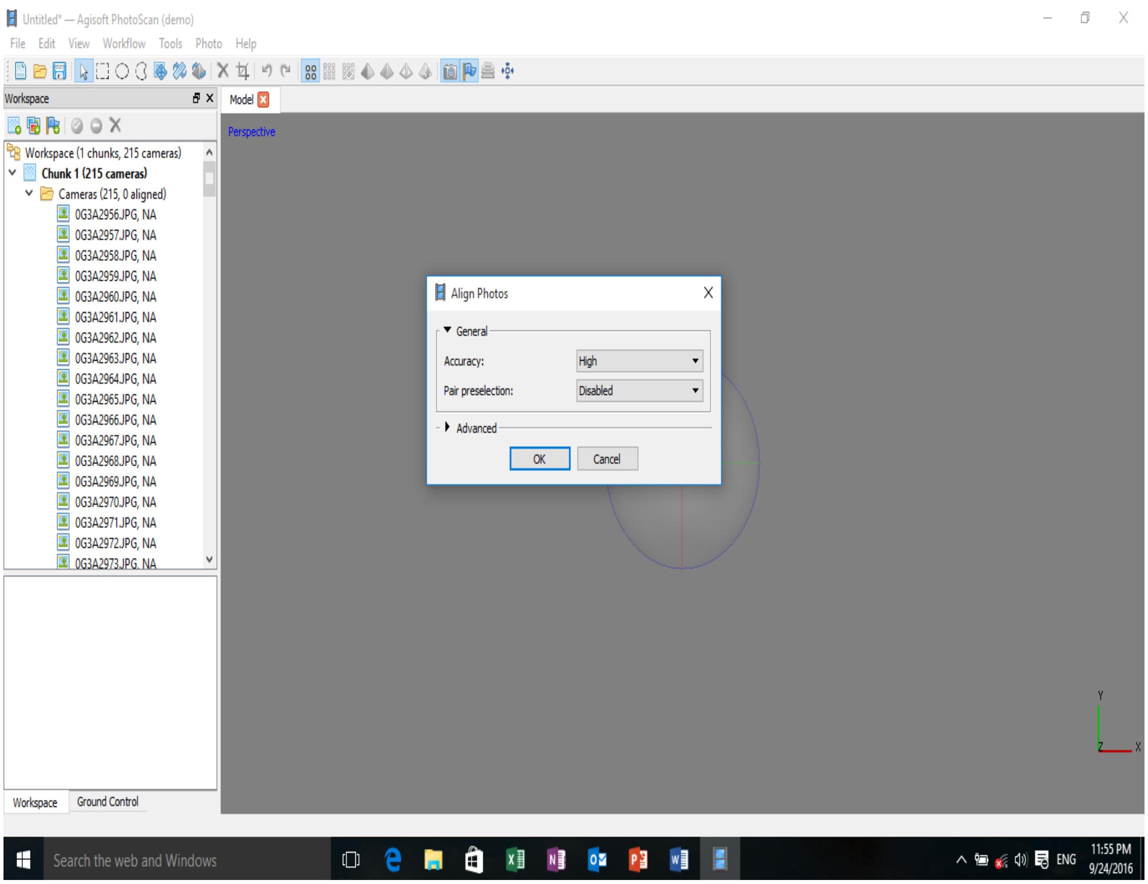


Fig 5.6, A Align photos

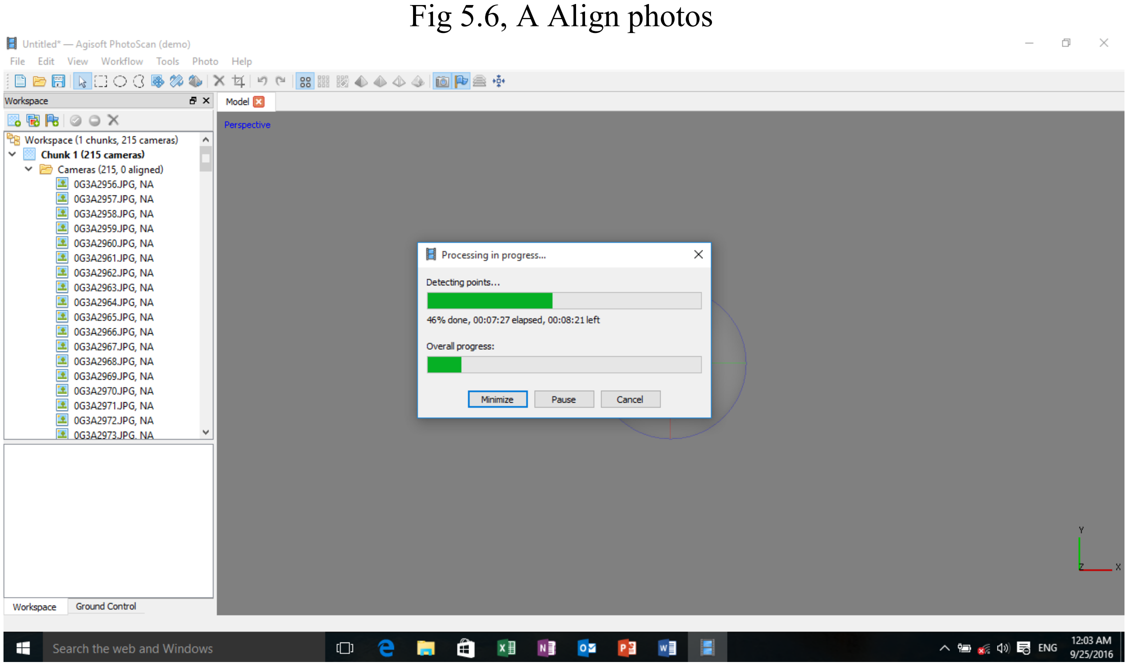


Fig 5.6,B Align photos and point processing

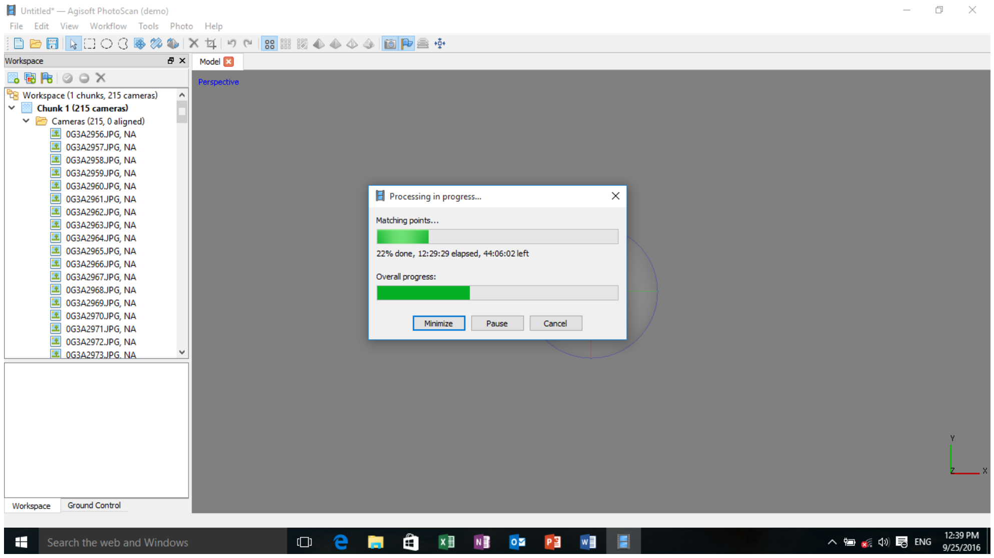


Fig 5.6,C Matching points processing

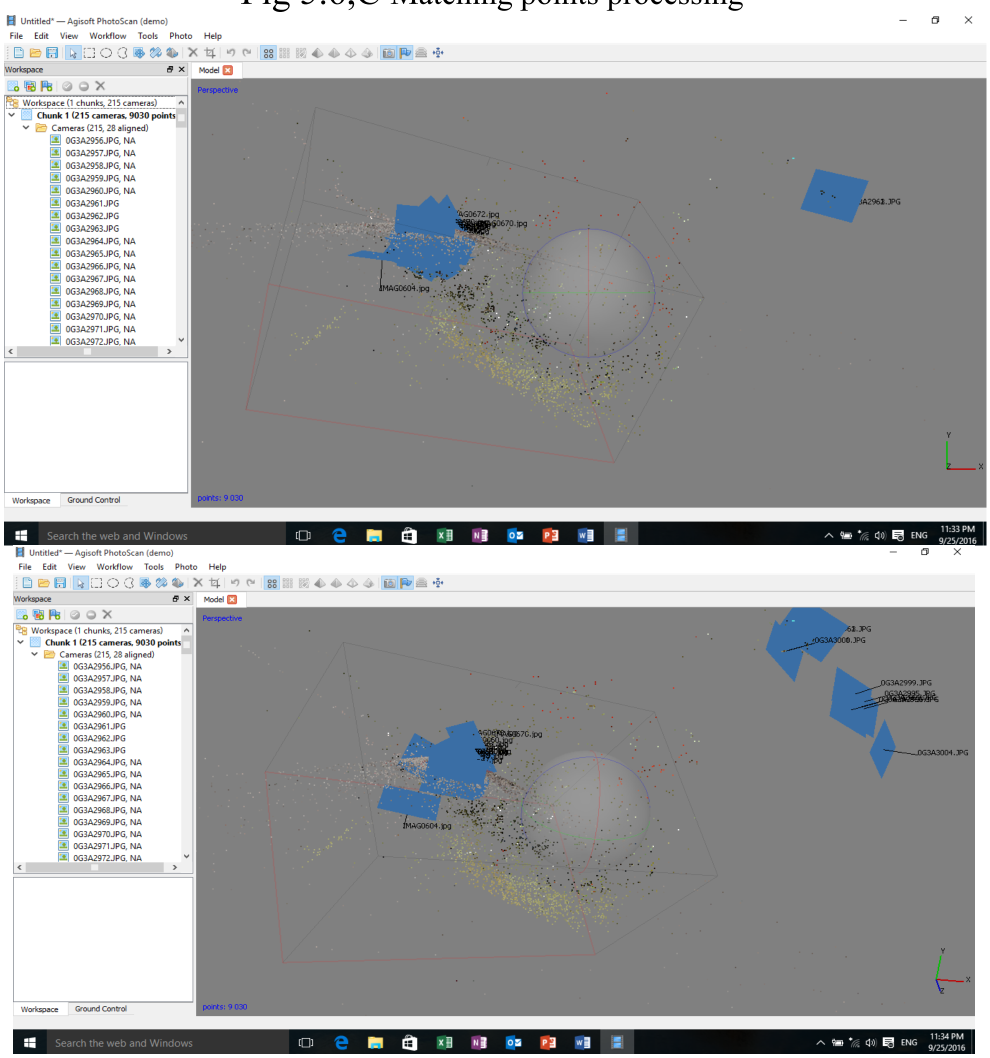
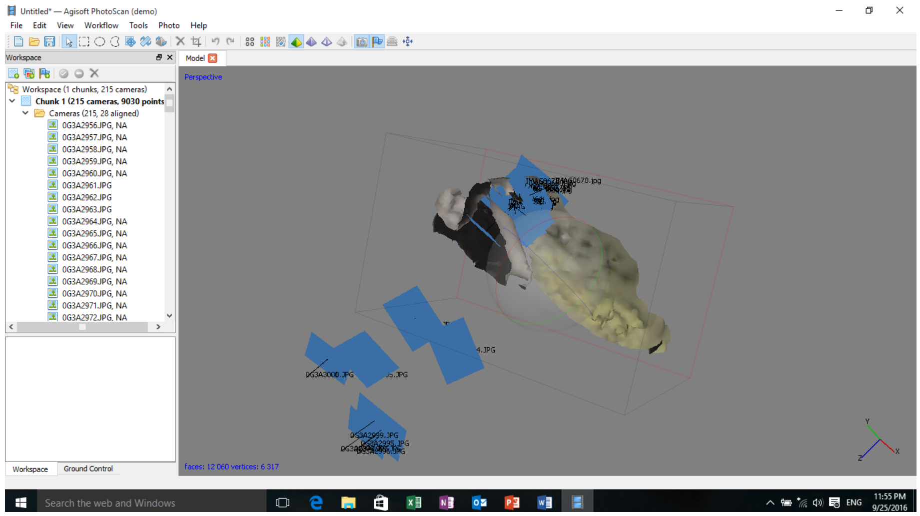
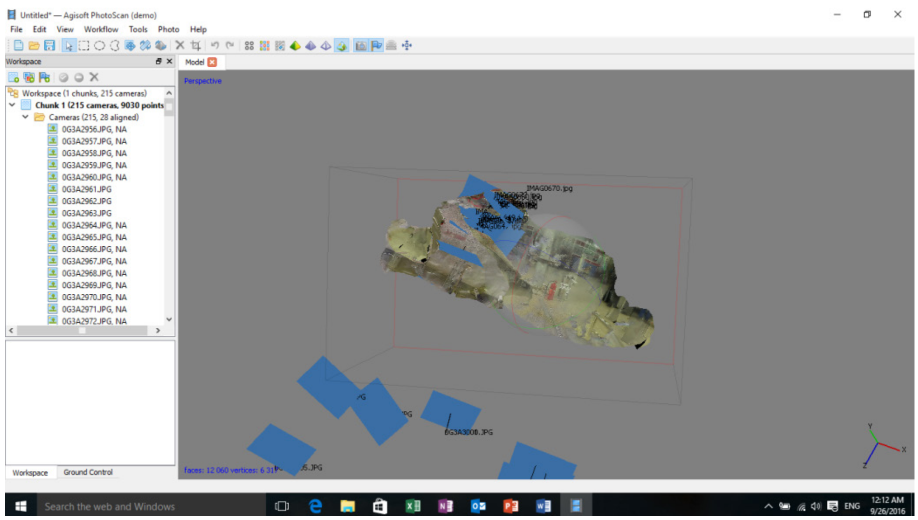


Fig 5.7, (a) Match the tie points and (b) align model



Build mesh



Build textual

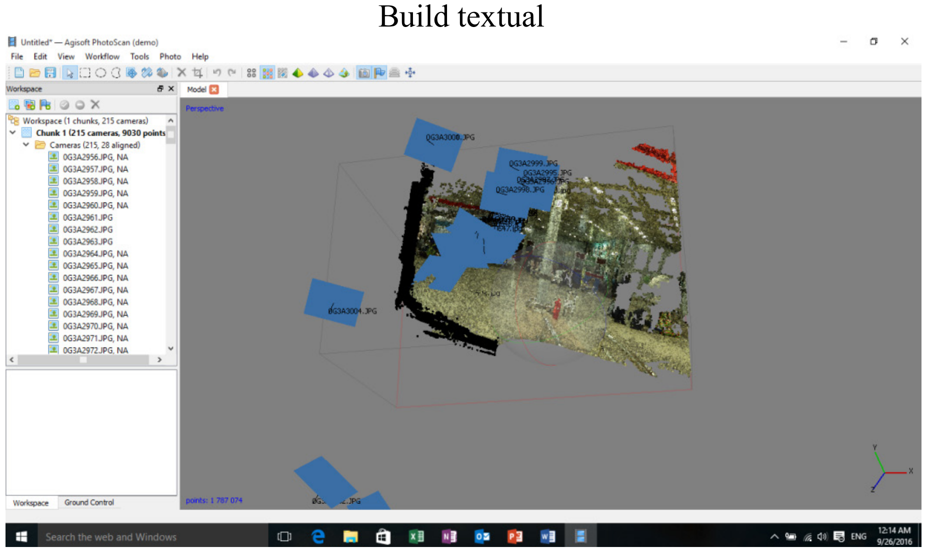


Fig. 5.8 (a) Build the mesh, (b) texture the point cloud and (c) provide a dense point cloud

5.3 3D Model Reconstruction

Reconstructing a 3D model is a combination of several processes or phases. 3D and 2D vector and raster data were created for the Region of Interest (RoI) using Trimble's SketchUp pro software and Esri's ArcGIS.

5.3.1 SketchUp

SketchUp software works well for texture mapping and allows to customize and duplicate any shape or repeated pattern. This procedure is useful for creating virtual reality models. The first step with SketchUp was importing the point cloud files and customizing the objects by filling gaps and clarifying building details and refining.

Undet Extension package was used for importing the point cloud (las format) files and adjusting objects. This works well with SketchUp (2015/2016 version) as an extension for importing numerous point cloud files, resulting from airborne LiDAR, Mobile Mapping Systems, Terrestrial Scanners, Handheld Scanners or Photogrammetry.

The 2nd step was adding texture for the model to be built by customized point clouds. SketchUp synthetic textures and image textures were used to guarantee better visualization and true virtual reality. This is demonstrated in Fig (5.9).

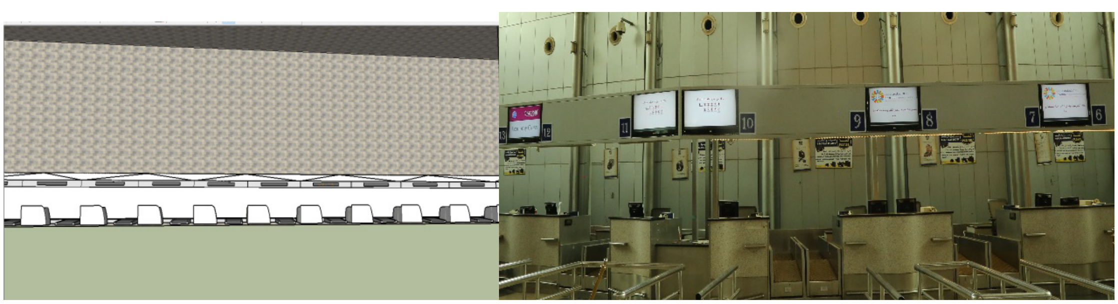
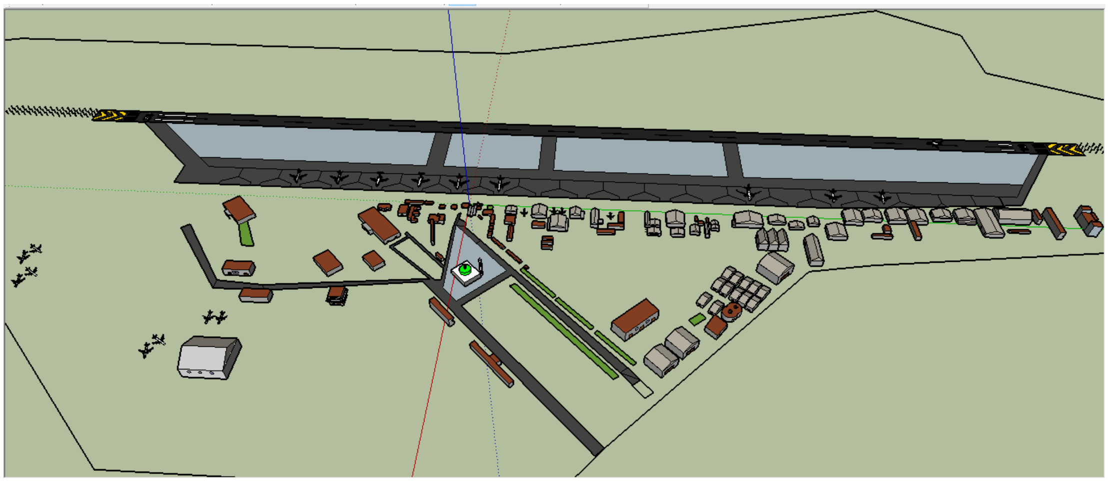
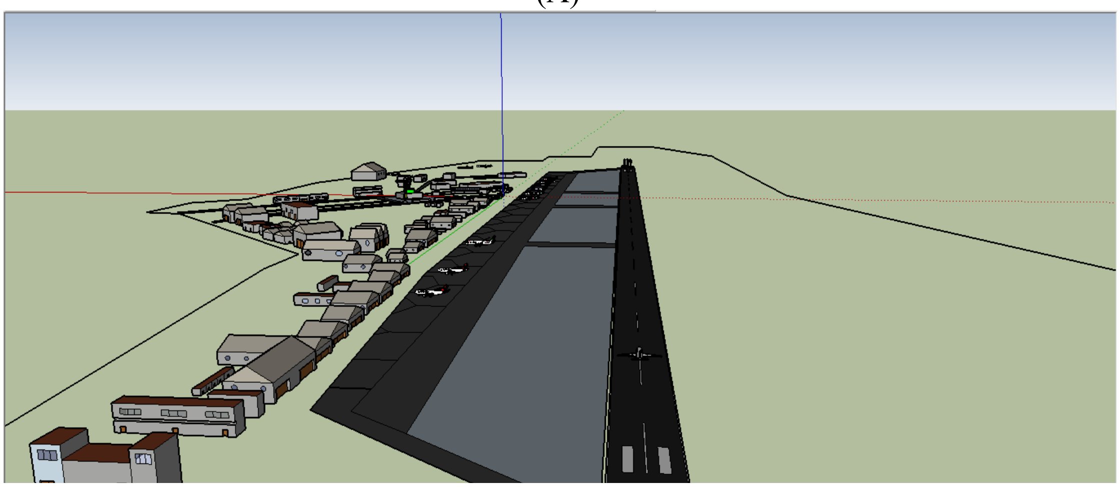


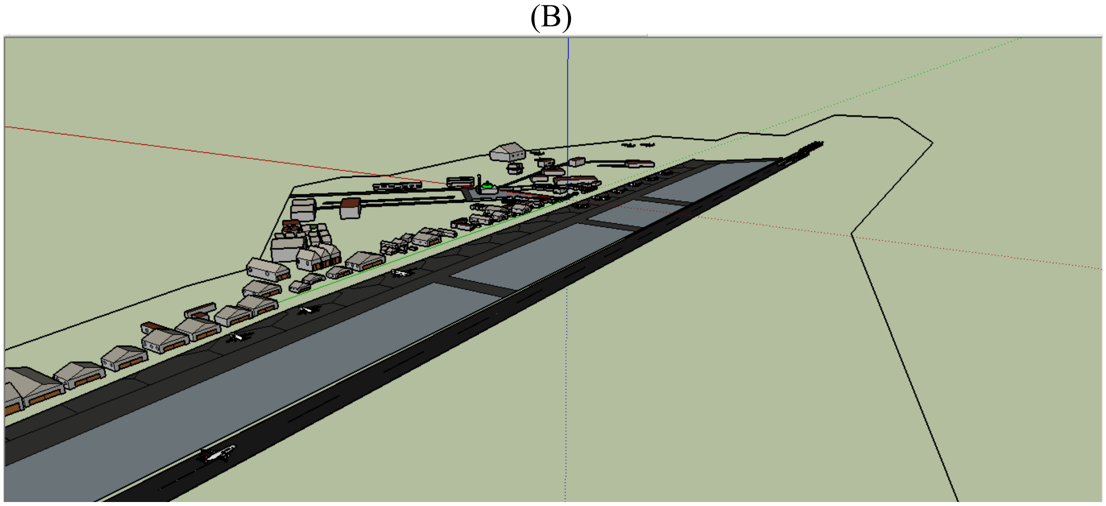
Fig. 5.9 Synthetic and real textures



(A)

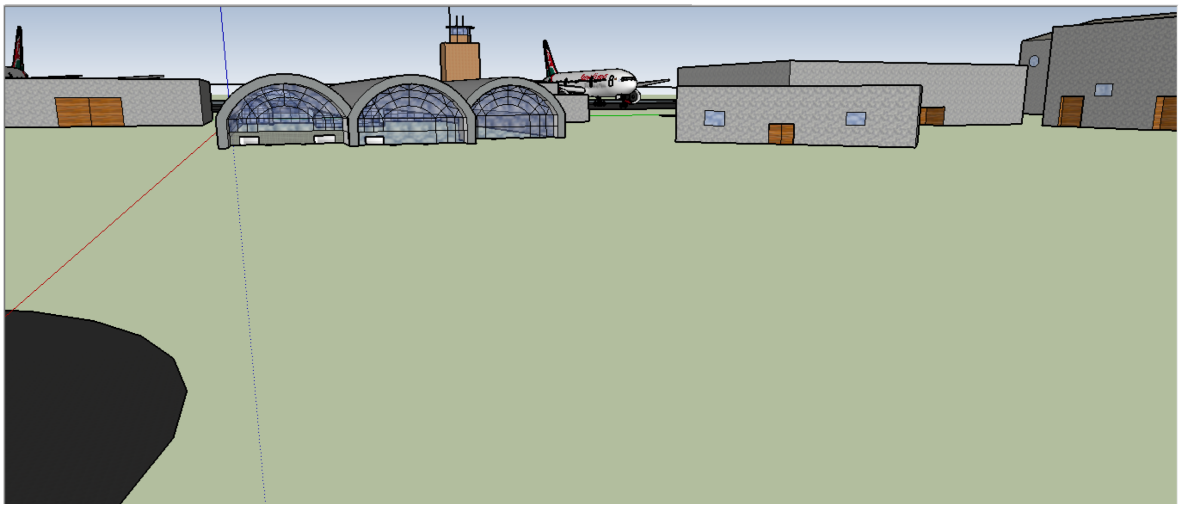


(B)

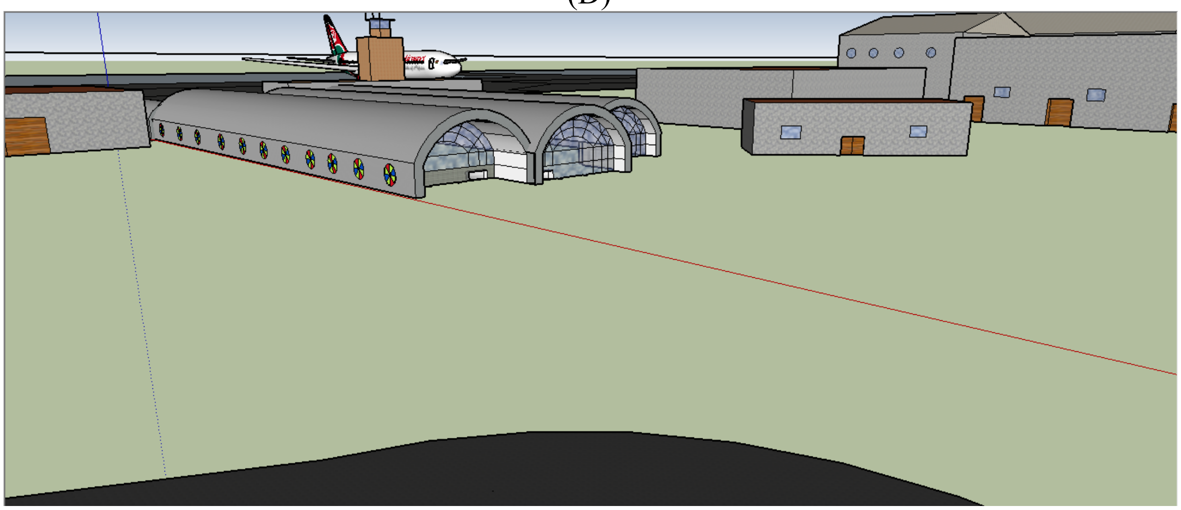


(C)

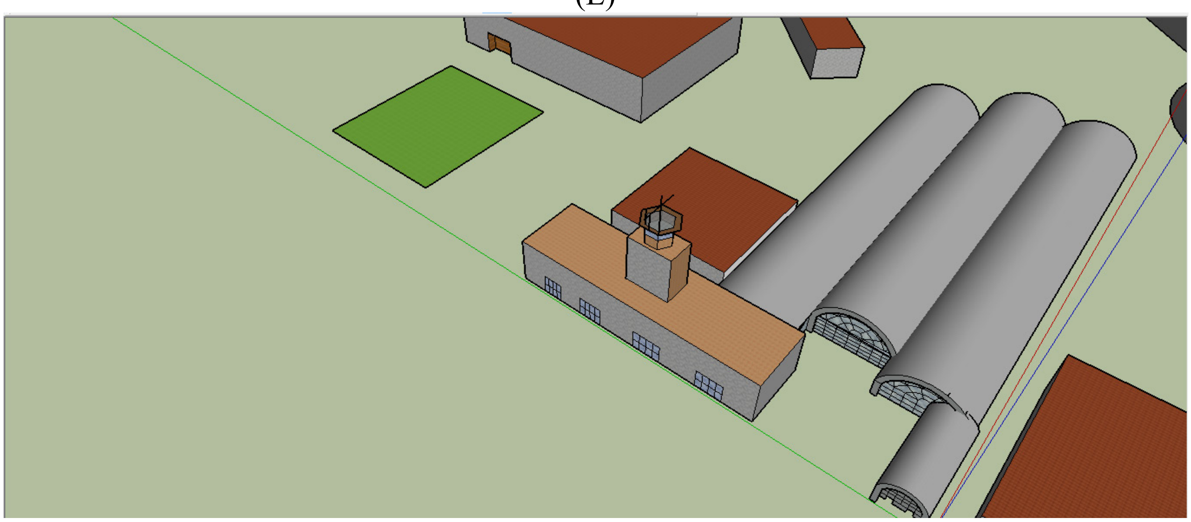
Fig. 5.10 (A, B, C): Final SketchUp results for Khartoum International Airport 3D Model, from different views.



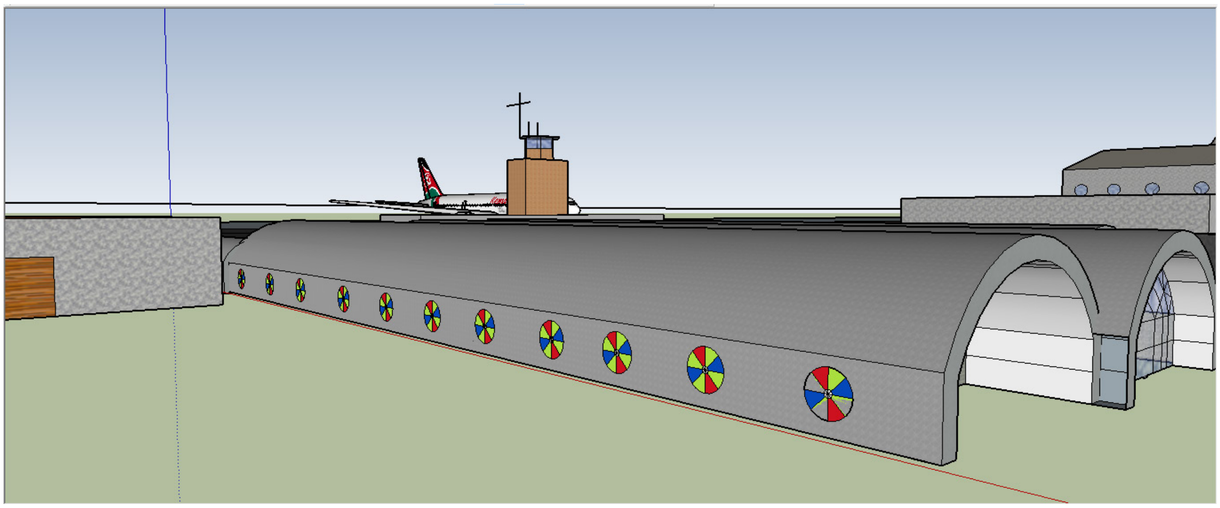
(D)



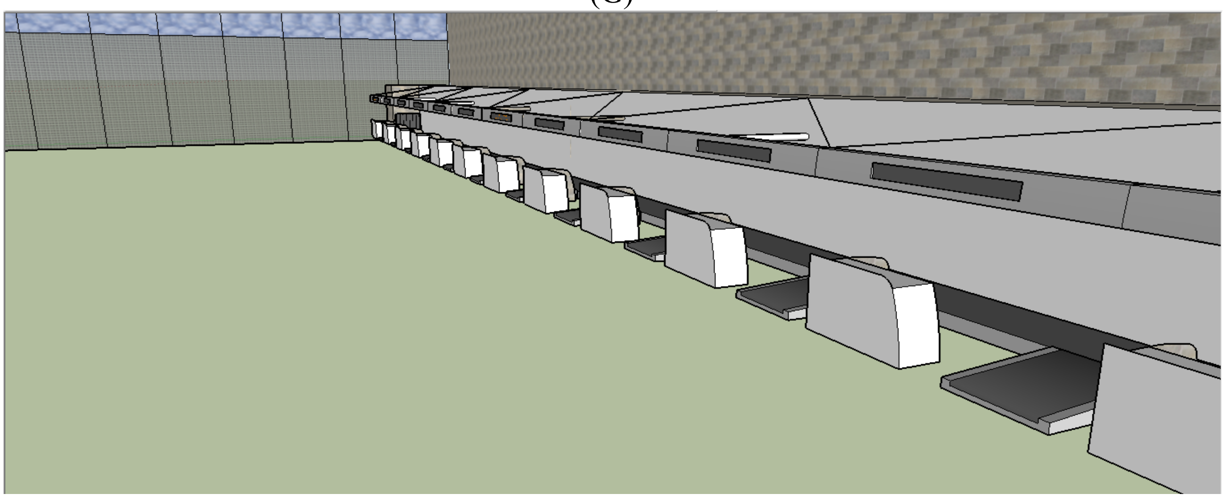
(E)



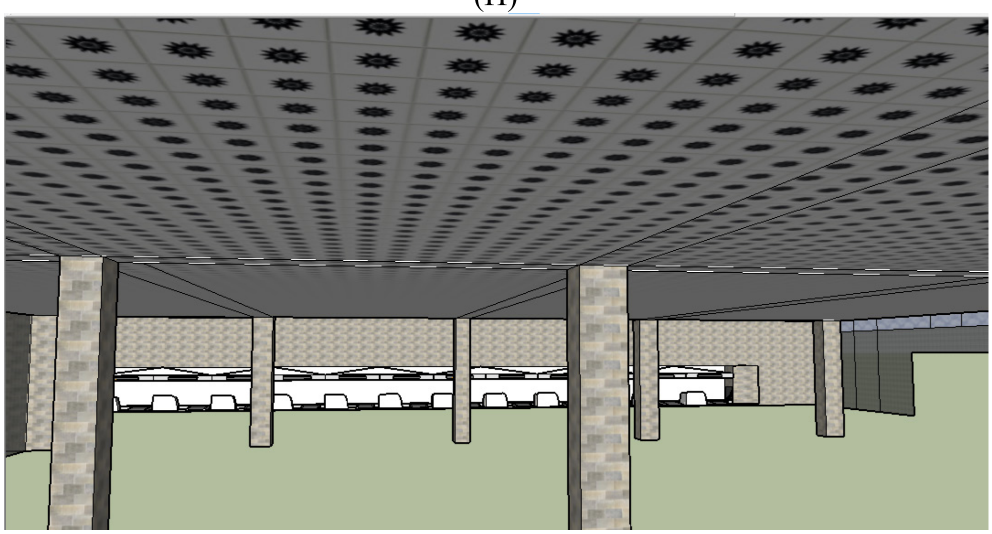
(F)



(G)



(H)



(I)

Fig. 5.11 (D, E, F, G, H, I): Final SketchUp result for Departure hall 3D Model from different views.

A 3D model has been extracted from this phase as a final textured model as shown in Fig (5.10) – (5.11), the output from this step is a 3D file in *.dae format.

5.3.2 **ArcGIS.**

ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database.

ArcGIS is one of (COTS) software's, that allow for emitting reality and building 3D geometric, vector and raster layers, and to provide geo-referencing. Analyses help in decision making. This step is concerned with extruding 3D buildings for 2D building vector layers – the results are 3D models, 3D buildings and the halls layer, as shown in Fig (5.9). Here a suitable coordinate system has to be chosen (vertical and horizontal) ′, for which we selected the World Geodetic System WGS 1984 UTM Zone [35,36,37]N, covering Sudan. Finally, the layers had to be converted to shapefiles as illustrated in Fig. (5.12), (5.13), (5.14), (5.15).

In this conversion to shape file take 26 minutes to convert Airport model to shapefile because the sensitivity of analysis this conversion illustrated in Fig (5.16), (5.17), (5,18).

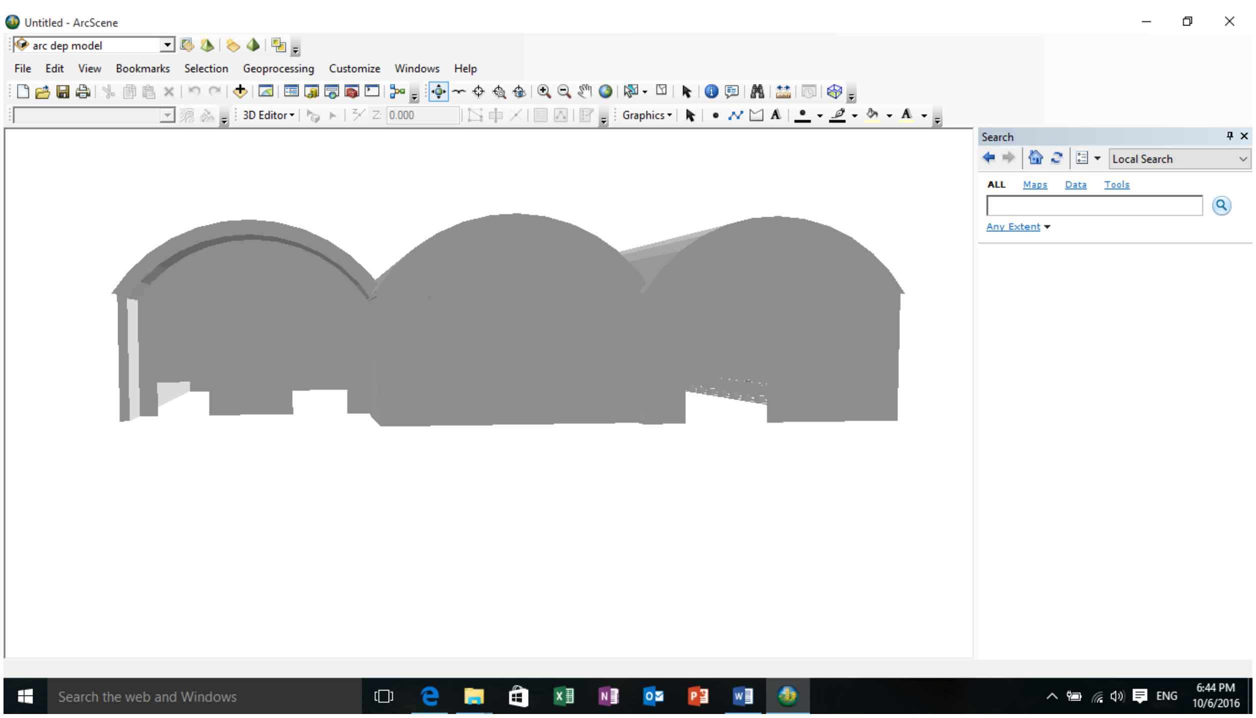


Figure (5.12) Departure hall shapefile

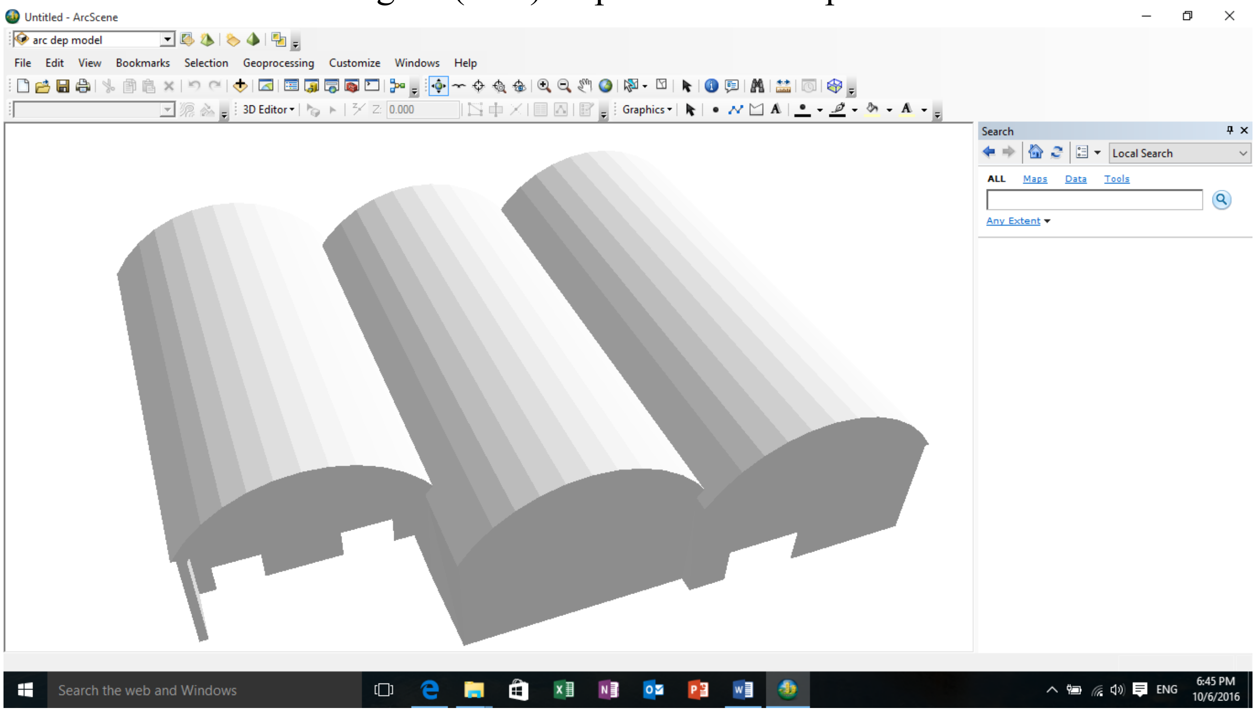


Fig. 5.13 Departure hall 3D Model from different views shape file

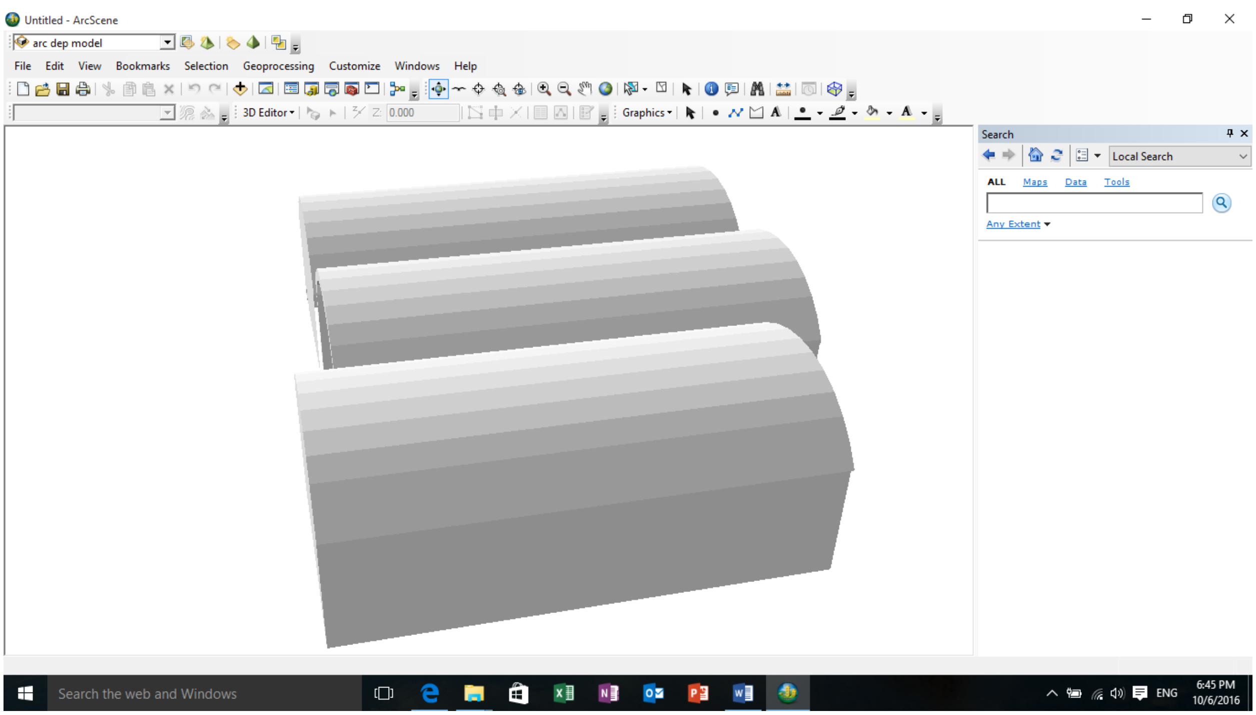


Fig. 5.14 Departure hall 3D Model from different views shape file

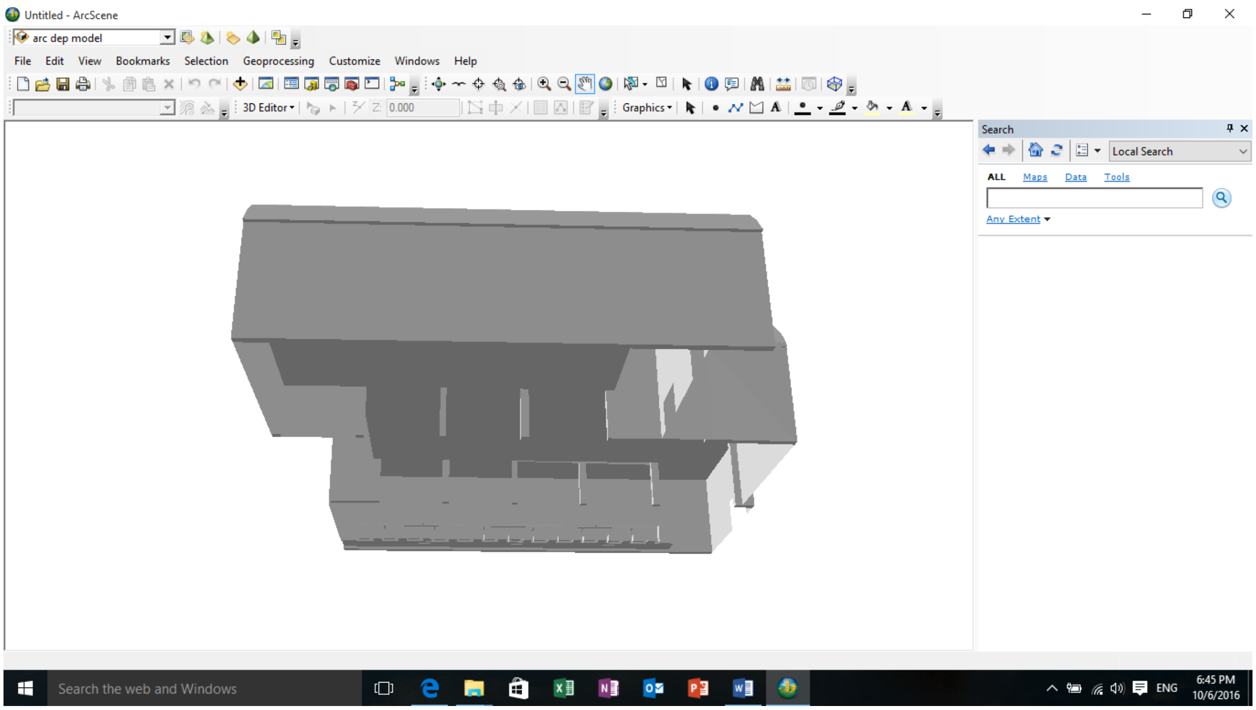


Fig. 5.15 Departure hall 3D Model from different views shape file

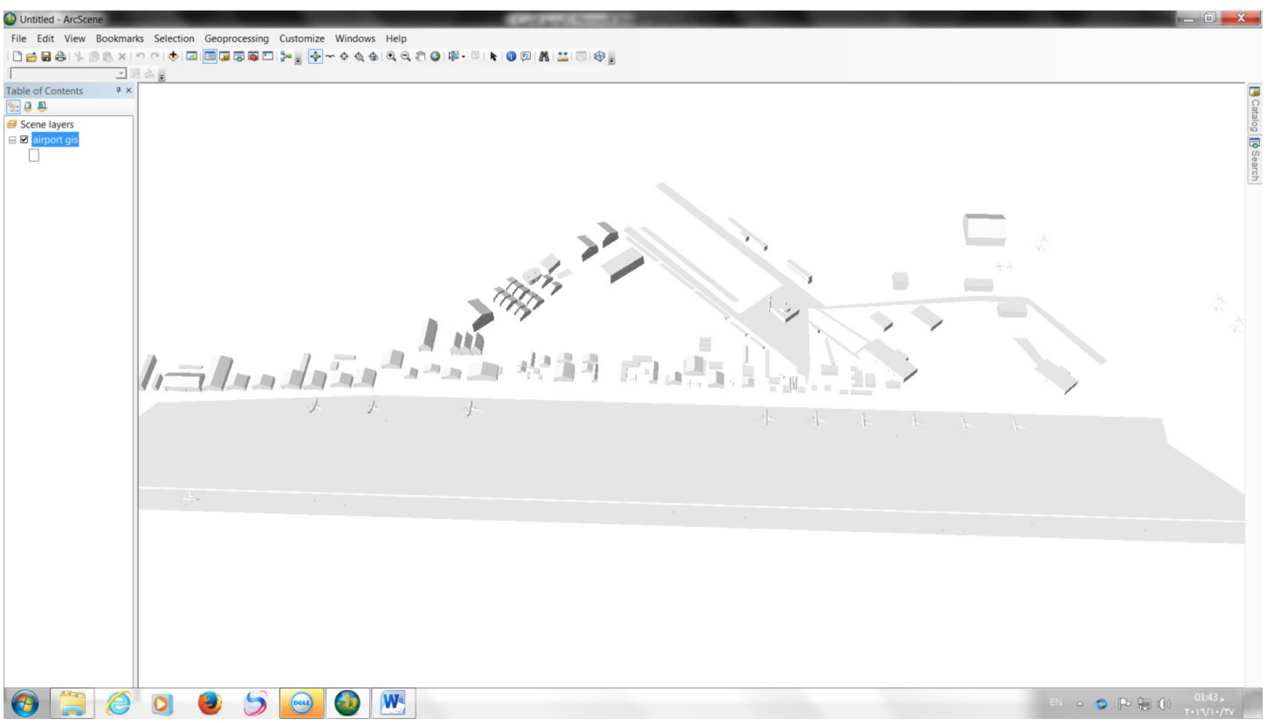


Figure 5.16 Airport shapefile

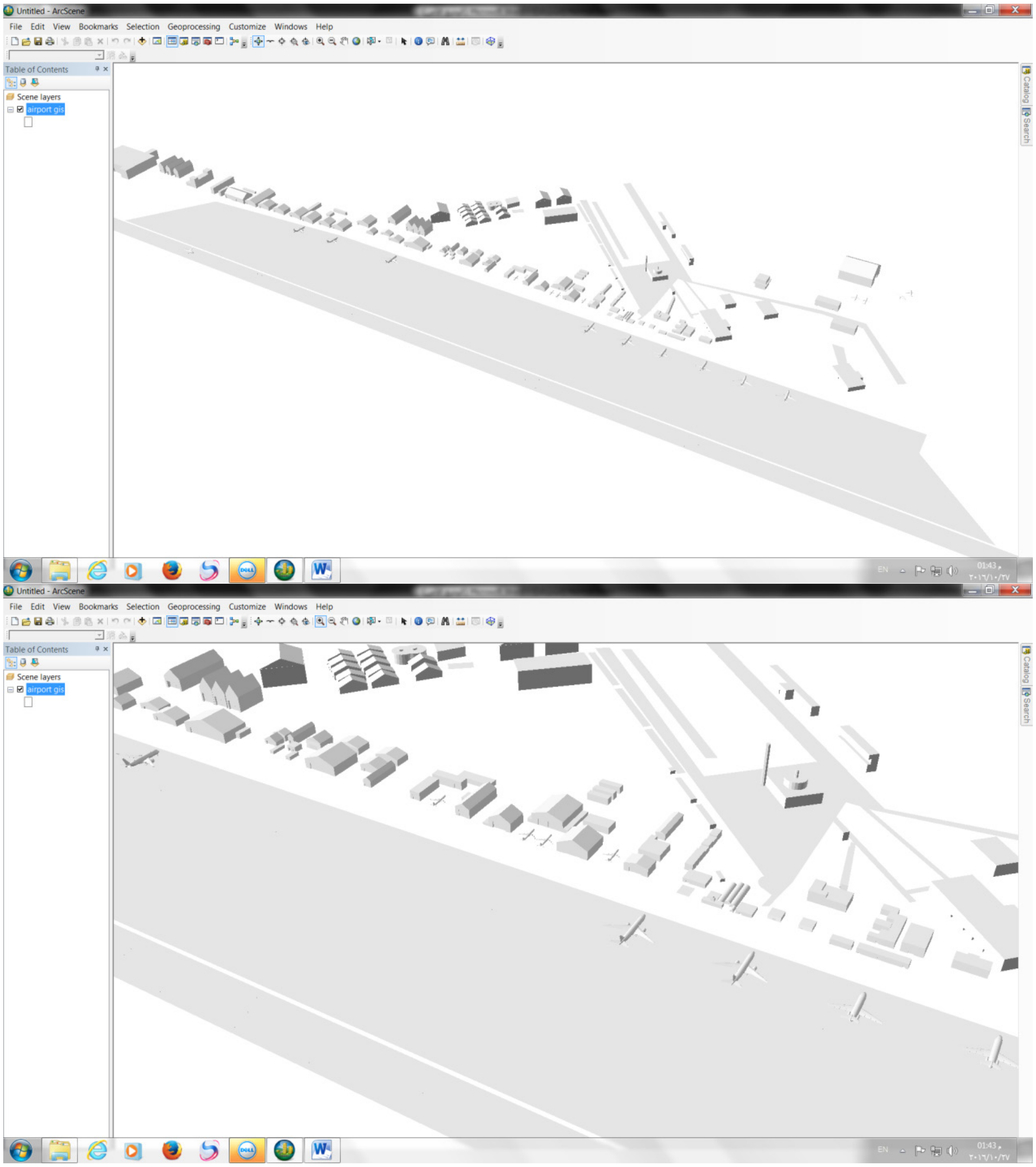


Fig. 5.17 Airport 3D model, from different views shapefile

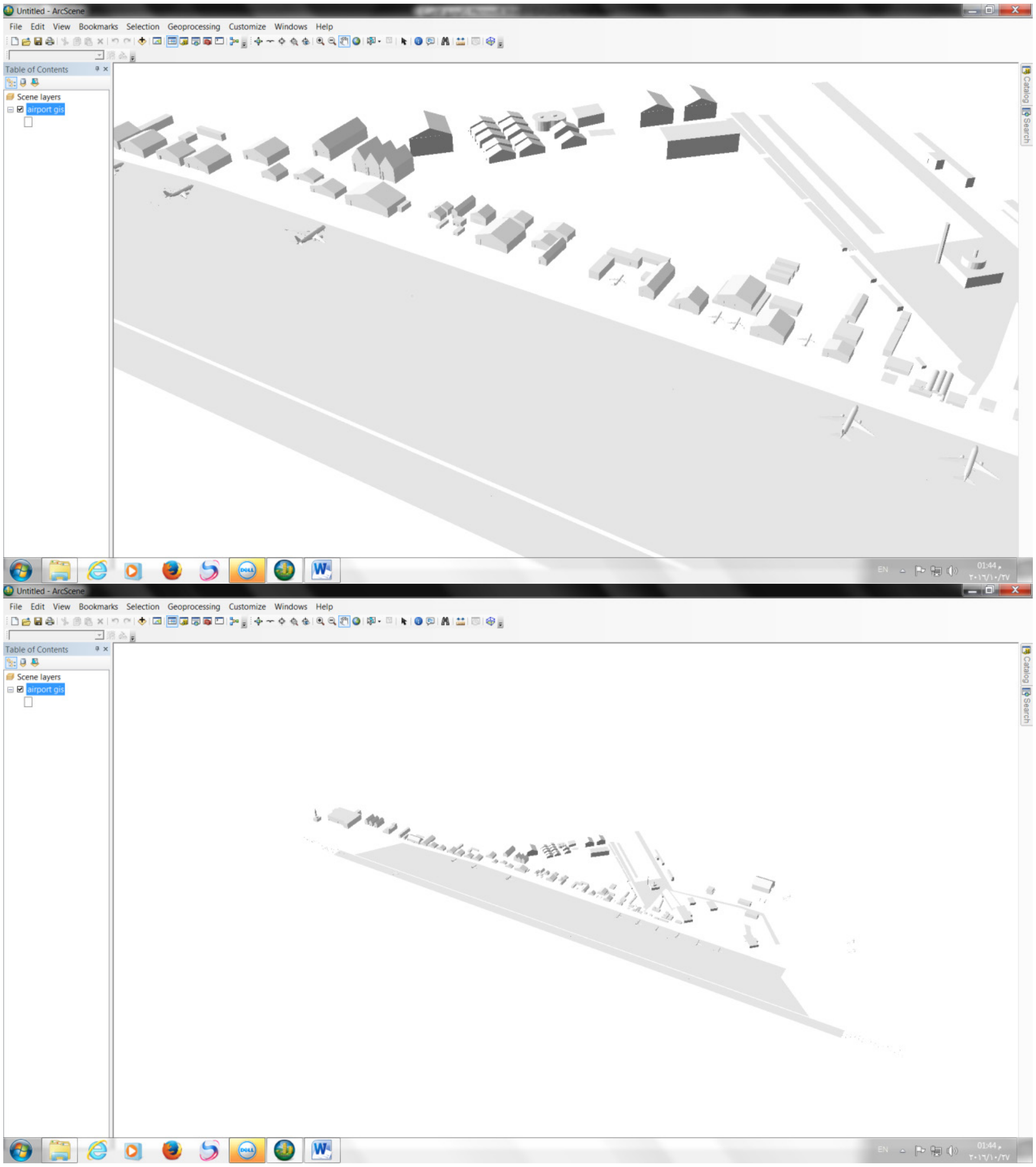


Fig. 5.18 Airport 3D model, from different views shape file

Chapter 6

Conclusions and Outlook

6.1 Conclusions

This work is the result of research that explores the effective use of 3D modeling in various applications. The thesis illustrates the feasibility of using photogrammetry and off-the-shelf software's in 3D GIS modeling.

Virtual reality modeling is used to build for the Khartoum International Airport a three-dimensional model with texture mapping, that allows for virtual reality visualizations, orientations and navigations around the whole Airport with georeferenced data and databases.

More and more fields now need and adopt technologies of 3D modeling. There are a number of directions in which we need to continue. Foremost among these is 3D model retrieval. To measure similarity of models, characters of 3D models, such as shape, topological construction and texture, are used. These characters are difficult to describe for users and complicated to calculate, while an effective retrieval function is necessary for an integrated 3D modeling system. Nowadays, the visual quality becomes one of the main points of attention. There is more and more demand for 3D content with higher accuracy. Information of scene and object could not be collected absolutely during the 3D data acquisition, and some data is inevitably lost, we could not recover the real word from videos or images by the current design. So, it is worthy for us to explore new methods to digitize the real world. Dynamic model is our new direction for the future work. Dynamic models can simulate reciprocal actions of objects, which is also very helpful in exploring the discipline of thing's evolvement.
The approach used in this work presents a simple strategy that is suitable for the development of realistic views of buildings and the introduction of an accurate virtual reality environment.

This thesis essentially aims at using GIS technology to guide passengers and administrators in their navigations over the Airport without wasting time and efforts.

6.2 Recommendations

For more efficient and real views, the following suggestions are recommended:

- Utilize GIS modeling for showing high level of building details, features and measurements

-Take advantages of GPS properties for user positioning

-Connecting Airport 3D model directly with the web site to access any time.

Chapter 7

References

7.1 REFERENCES

7.1 References

[1] Arayici, Y. & Hamilton, A. Modeling 3D Scanned Data to Visualize the Built Environment. Proceedings of the Ninth International Conference on Information Visualization, 2005, ∼5 09 514

[2] Sainz, M., &Pajarola, R. &Mercade, A. A Simple Approach for Point-Based Object Capturing and Rendering. IEEE Computer Graphics and Applications, 2004, ∼July/August: 24 33

[3] Brand, M. &Kang, K. & Cooper, D.B. Algebraic solution for the visual hull. Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and ∼P attern Recognition, CVPR 2004, I33 I35

[4] Huisman, O.& Rolf, A., 2009," Principles of Geographical Information Systems", The International Institute of Geo-Information Science and Earth Observation (ITC),2009, pp. 32-49.

[5] Münster, S., 2010, "Workflows and the role of images for virtual 3D reconstruction of no longer extant historical objects", Dresden University of Technology, Germany, 9/2013, pp. 2-5 and pp. 198-201.

[7] Al-Hanbali, N., 2007," Texture Mapping and Implementation Aspects for 3D GIS Applications", Research Paper of Al-Balqa Applied University, 12/2007, pp. 2-16.

[8] Al-Rawabdeh, A., Al-Ansari, N., Attya1, H. &Knutsson, S., 2014,'' GIS Applications for Building 3D Campus, Utilities and Implementation Mapping Aspects for University Planning Purposes'', Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA, pp 4-9.

[9] Agisoft LLC ,2013, "AgisoftPhotoScan User Manual", Professional Edition, Version 1.0.0, pp 1.

[11] The University of Maryland Libraries,2012," Spatial Analysis Using ArcGIS 10", user manual, pp 2.

[10] "SketchUp Pro", (May 22, 2016) retrieve from http://www.reuters.com/article/ustrimble-google-idUSBRE83P0V820120426.

[12] "about sketchfap" (May 22, 2016), retrieve from https://sketchfab.com/

[13]"about photogrammetry"http://www.photogrammetry.com/

[14] "about ArcGIS"http://www.esri.com/software/arcgis/arcgis