INTEROPERABLE THREE-DIMENSIONAL GIS CITY MODELING WITH GEO-INFORMATICS TECHNIQUES AND 3D MODELING SOFTWARE

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ABSTRACT:

A working integration of three-dimensional models with geo-referenced database holds great promise for large scale spatial study. In the past, the work was separated and difficult to combine between geo- referenced and 3D model databases while the needs of reliable and quickly 3D data was increasing. Until now, the rapid evolution of three-dimensional GIS technology and integrative modules, plug-ins and software seem to be outpacing course content in academic setting.This paper aims to describe the integration of geo-informatics techniques with 3D modelling software to develop three-dimensional GIS database which includes reconstruction of buildings, terrain, and other features that are relevant to a city model. The techniques used in the creation of a 3D GIS city model has been provided by the GIS environment and assisted by a high resolution satellite images used digital photogrammetry and 3D modelling software. The reliable data are prepared from digital photogrammetry and image analysis process using high resolution satellite image, then the data extraction continues to develop GIS database. The Google SketchUp Pro is selected for reconstruction of buildings with the reason that it is easy to use and ready for distribution. Compared with other modelling software, SketchUp's short learning curve and simple user-interface provide a straightforward vehicle for three-dimensional modelling. The simple transition between two-dimensional surface and three-dimensional extrusions let users efficiently translate source data to three-dimensional. Users can quickly develop three-dimensional models that are geo-referenced. The result shows that the efficiency of integrated technique to 3D GIS database development which is reliable and fast. The big challenge for the future work is the study of a new development approach for 3D generalization of spatial objects that will be used to improve the efficiency of 3D map visualization.

1. INTRODUCTION

1.1 Overview

Map visualization is often considered as important as the map content. In community planning, a GIS map is typically used to model reality. While good analysis is important and data quality is a key factor, the most critical matter is the method of communication. When GIS information is presented using appropriate visualization techniques, it can stimulate public participation. A three-dimensional GIS simulation always communicates more effectively than two-dimensional. Imagine being able to experience a proposed development project by walking, driving, or even flying over it, regardless of time and season, while the project is still in its conceptual stage. (Meenar and Ambrus, 2006)

With the rapid development of technologies in the recent years, 3D GIS have emerged as a reality. Creation of 3D digital city model using conventional stereo images of aerial photos or satellite images is cumbersome and is a less cost-effective technique for many applications, (Jalli and D, 2007). Planners, urban designers, landscape architects, and other planning professionals use computerized visualization techniques to encourage participation of the public. Many of the techniques they employ can be incorporated into a GIS, (Meenar and Ambrus, 2006).

Currently, most GIS users are using 2D mapping model, but the rapidly growing interest in 3D models is increasing and rendering techniques are being developed. The use of 3D functions is particularly powerful for the creation of DEMs and 3D visualization models which are used in a very wide range of application, (Naidoo and Mohamed, 2007).

3D mapping was, until recently, the exclusive domain of geo-information practitioners. It required expensive and highly specialized software. Beside the extension of the popular GIS software, there have been many software commercials available for performing 3D analysis of the spatial data. Today, freely available software such as Google Earth has made 3D mapping accessible to the public and has spurned a new and huge demand for three-dimensional maps.

1.2 Objective

The main objective of this study is a working integration of three-dimensional model with geo-informatics technique. The aim of this study needs to be answering for 3 main ideas that supported the concepts of georeferenced database which is holds great promise for reliability, accuracy, and time.
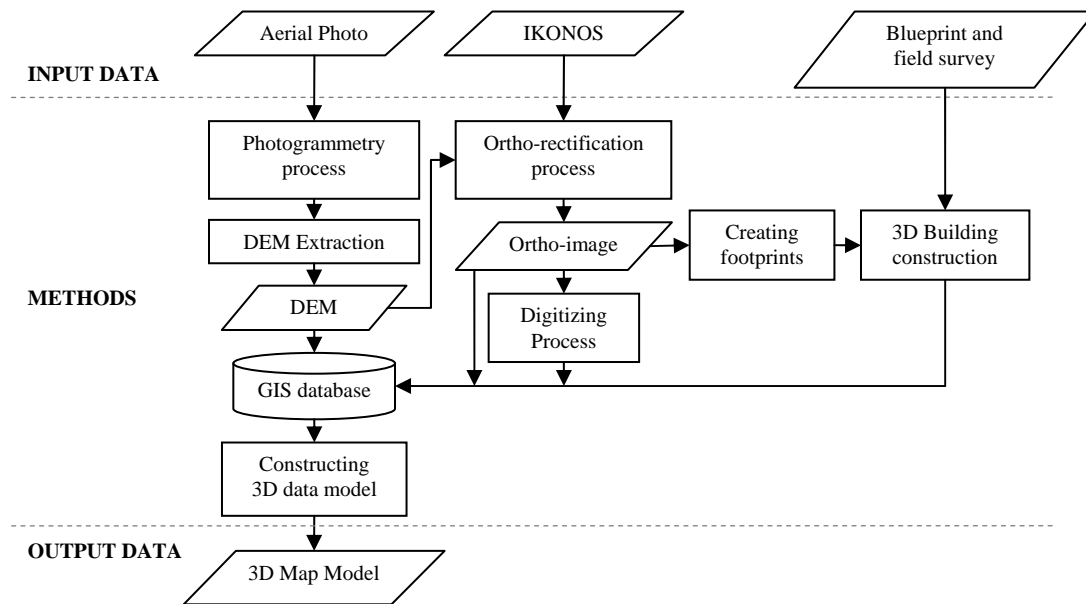
Figure 1. The frame work of the 3D map model development

1.3 Study Area

Chiang Mai University have three campuses (Suan Sak, Suan Dok, and Mae Hea), which together cover about 3,490 acres of land. The study area is in the main University campus, Suan Sak campus, lies about 5 kilometres west of the city center. Set against the backdrop of Doi Suthep mountain, the campus occupies a 725-acre site. This area is composed of the university's administrative centre, the faculties, the graduate school, all of the campus resource facilities and services, and major sports facilities. An attractive feature of this campus is the Ang Kaew Reservoir. Constructed to supply water for the University, it also provides an idyllic recreational area for both campus residents and the local community.

The main reason to select the study area that it is contained the variety of building, i.e. the large-size building of faculty, medium-size building of office, and small-size building of house. Especially, the buildings of faculty have the variety style and situated on vary terrain which is good for testing the 3D map model development.

2. METHODOLOGY

This study involved 4 main working processes: photogrammetry process, Ortho-rectification process, creating footprint of a building and tree-dimensional map model. Photogrammetry process dealt with the creation of DEMs from aerial photos. Ortho-rectification process dealt with the modification of IKONOS high resolution imagery into ortho-image to make footprint of a building. The examination of the building's height and its other features was done to support the making of three-dimensional footprint. Then, all data was gathered to create three-dimensional map model.

2.1 The Photogrammetry Process

2.1.1 Data preparation: The aerial photo images are scanned by high performance scanner from diapositive film, 15 micron (1,600 dot per inch), prepared for photogrammetry processes.

A ground control point (GCP) is feature to identify in the raw image for which is known ground coordinate. The main of photo control point were specified which is reference from Royal Thai Survey Department. Another points selected on photo consider by the standard of photo control point specification and the landmark in area which are transferred the coordinate from the main control point via GPS survey technique.

The techniques for surveying and controlling of GCPs are also very important in the GPS measurement to get the coordinate for photogrammetric adjustment. The dual frequencies GPS geodetic type instrument was selected for coordinate measuring in this study. It will be used n coordination with SKI-Pro GPS Post-processing Version 2.0, software to calculate and adjust the data from GPS measurement.

The GPS measurement in this study uses the static survey technique gives high accuracy position. GPS will be setup at every 3 control point to receive signal for 1 hour per session. After that, the GPS data will be corrected by Least-squared Adjustment – the correction technique to data adjustment and quality testing of measurement –divided into 2 steps, horizontal coordinate correction had been giving geodetic coordinate and local UTM coordinate refer to WGS84 horizontal datum, vertical correction had been giving mean sea level height.

Geometica OrthoEngine is a powerful photogrammetric tool designed to handle small and large production workloads to efficiently produce quality geospatial products. OrthoEngine's interface is organized along logical workflows to produce orthorectified images, digital elevation models (DEMs), and mosaics. This structure provides with a more intuitive workflow. They are divided 3 main steps set up the project, compute the math model, and generate the deliverables.

2.1.2 Setup the project: The Aerial Photography Math Model is a rigorous model based on the geometry of a frame camera. This model can compensate for the effects of varying terrain and for the distortions inherent to the camera; such as the curvature of the lens, the focal length, the perspective effects, and the camera's position and orientation. The computed math model calculates the camera's position and orientation at the time when the image was taken.

When the project was setting up, the type of math model, the projection system, and the parameters for interior orientation had specified which are aerial photography math model, WGS84 UTM coordinate system, and camera calibration's values.

2.1.3 Compute the math model: Exterior orientation represents a transformation from the ground coordinate system to the photo coordinate system which is computed from ground control points (GCPs) and tie points. The exterior orientation is the position and orientation of the camera when the image was taken. In other words, it is the relationship between the ground and the image.

A tie point is a feature that are clearly identified in two or more images and selected as a reference point. Tie points do not have known ground coordinates, but use them to extend ground control over areas where there are not ground control points.

GCPs and tie points collection is the method to input the coordinates of ground control points that received from GPS survey to aerial photo images. OrthoEngine collects tie points and performs exterior orientation automatically.

The bundle adjustment is simply the computation of a rigorous math model. It is a method to calculate the position and orientation of the camera at the time when the image was taken. Once the position and orientation of the sensor is identified, it can be used to accurately account for known distortions in the image.

In the Aerial Photography math model, the geometry of the camera is described by six independent parameters, called the elements of exterior orientation. The three-dimensional coordinates x, y, and z of the exposure station in a ground coordinate system identify the space position of the aerial camera. The z-coordinate is the flying height above the datum, not above the ground. The angular orientation of the camera is described by three rotation angles: Omega, Phi, and Kappa.

2.1.4 DEM extraction: Digital elevation model (DEM) is created from stereo pairs of images. The epipolar image is used to extract the features in three-dimensional (3-D) stereo editing. The contour line, height points and break line will be created then used for DEM generation.

2.2 The IKONOS Ortho-rectification

Due to the reason that the aerial photos were an outdated data, IKONOS high resolution imagery 2005, which illustrated more modern data, was employed as fundamental data to obtain information of roads and buildings in the study area. This information was, then, passed through ortho-rectification process to obtain ortho-image by the use of Rational Function Rigorous Math Model Method. The method controlled the coordinates and the accuracy with GCPs, which obtained from GPS survey. After that, DEM was employed to modify the information to obtain ortho-image.

2.2.1 Data preparation: IKONOS Geo Ortho Kit product provided a Geotiff combined with a text file that contains rational function coefficients, called Image Geometry Model (IGM) or Rapid Positioning Capability (RPC). The Ortho Kit product also contains no orbit data, but the text file provides the coefficients to define the Rational Functions math model.

OrthoEngine includes rigorous math model that produces robust ortho-rectification of satellite imagery such as IKONOS data. They are divided into 2 main steps, set up the project, and generate the deliverable.

2.2.2 Setup the project: The Rational Functions Math Model was selected for IKONOS image ortho-rectification which is a simple math model that builds a correlation between the pixels and their ground locations. This math model can be used in several cases such as when the data is missing the information needed for a rigorous math model, when the sensor model is proprietary (classified), when the image has been geometrically processed, when the data provider computed the math model and distributed it with the image, or when you do not have the whole image.

2.2.3 Generate the deliverable: IKONOS image ortho-rectification is based on rational function math model with RPC and the GCPs collection. After importing IKONOS image with RPC, the ortho-rectification will be processed with DEM that were prepared from the above process.

2.3 Creating Footprint of a Building

The obtained ortho-image acted as fundamental information for the process of digitizing information of roads and buildings through Geographic Information System (GIS). The digitizing process of a building's structure to make footprint in order to create three-dimension building model would mainly examine the building's structure and add various detail to the building that could be seen from ortho-image. These details included the roof pattern and other features of the roof. This also included the setting of the building's height obtained from blue print and turning it into numeral features in attribute data of each building for illustrating three-dimensional buildings.

2.4 Three-dimensional Map Model Development

All data prepared in GIS would be passed through program to create three-dimension model. In this study, Google SketchUp Pro 6.0 program was employed because it was inexpensive, easy to work with, effective, and able to apply with GIS program.
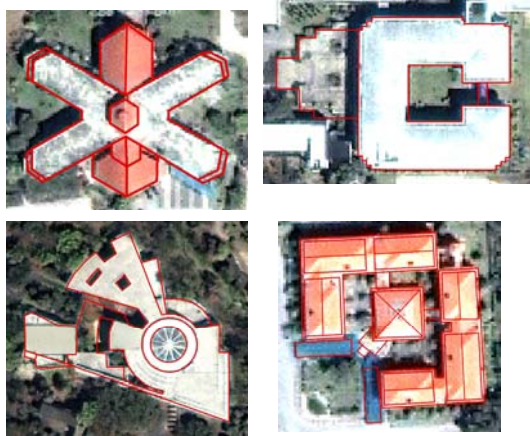
Figure 2 footprint creation from ortho-image

The data passed to Google SketchUp Pro 6.0 program included Shape file, which was the building's footprint and TIN data. Then, Google SketchUp Pro 6.0 program was applied to create three-dimensional building models from the footprint then added and modified detail to the buildings for more completion. Finally, the detail of the three-dimensional buildings was converted into detail that set in GIS in Format ESRI Multi-patch for illustration.

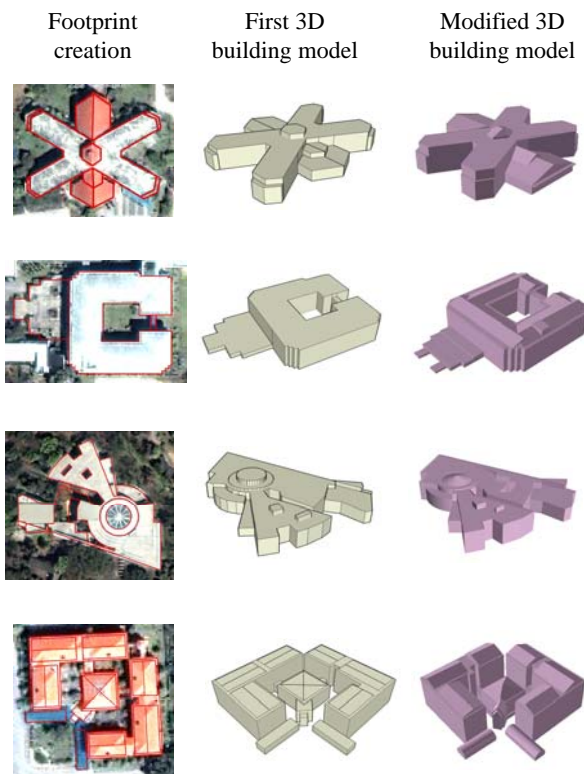| Footprint creation	First 3D building model	Modified 3D building model

Figure 3 Steps of building model creation

All completed data was examined to illustrate in GIS by ArcScene program. TIN data was used in the illustration of terrain and add more detail to the buildings in three-dimensional form to illustrate on the terrain. Moreover, the road's data and

ortho-image of IKONOS referential to the TIN height to illustrate three-dimension map were added for more completion.

3. RESULT

The outcome of this study was three-dimension map model which was able to illustrate more accurate spatial data. The users could have greater view and more understanding with data in the map, especially, the accuracy and reliability of positions of spatial data controlled in the working processes.

Figure 4 Result of 3D Map Model

The three-dimensional scene is including the solid box representation of the building messes work fine based on the terrain. Ortho-image has been draped on the terrain to create the backdrop that compensates for the absence of other features such as trees, roads, and reservoir. ArcScene allow users to interactively move on the fly over the area, rotate, zoom in, and zoon out.

The technical limitation was effected by the complex three-dimensional data. Time is required for visualization processing. For larger datasets which are created in this study, computer processing and refreshing time may become unacceptably long.

4. CONCLUSION

Today, software technology of Geo-informatics and 3D modeling can be working together. This results in more accuracy and reliability of the creation of three-dimension map model, especially, 3D modeling program such as Google SketchUp Pro 6.0, which was developed to be uncomplicated for the users and, also, less expensive. It believes that, in the future, three-dimension map model would be consistently developed.

However, challenges are still existed. This includes the acquisition of accurate and reliable spatial data, which requires high knowledge and techniques. Also, the working processes are complicated and take times to develop the database. This work needs tools that are effective enough to complete the processes. In addition, to make three-dimension map model more accessible to the users, various techniques should be developed for more simple use.

Moreover, the challenge in the illustration of three-dimension map model is the illustration of data fit to the map scale, especially, the illustration of three-dimension map model which is variable in scales, due to its consistent interaction with the users. Therefore, 3D map generalization should be taken into

consideration and should be develop into an automatic illustration of three-dimension map model for highest beneficial to the users.

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