# AN EFFICIENT 3D GIS DATA EXTRACTION METHOD WITH DIGITAL PHOTOGRAMMETRY TECHNOLOGY IN ARID AREA

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## ABSTRACT

Three dimensional (3D) features are important geometry information for environmental analysis and GIS applications.  It is critical for GIS related virtual modeling.

Comprehensive Multilevel Modeling (CMM) method is apparently useful in implementing GIS modeling from national level to internal level.  3D GIS features could be extracted quickly based on national strategy and local application requirements following CMM architecture.  By using this method, it is possible to extract 3D features for special applications where only a specific area is interested by researchers.

Digital photogrammetry technology is one of the popular methods for 3D features extracting.  In according to the requirements for digital stereo modeling, a series of ground control points (GCPs) and tie points should be collected before the precise model established.  However, it is hard to collect enough GCPs in some areas such as desert where the special landscape characteristics are existed.  This would influence stereo modeling.

Google Earth model has demonstrated high accuracy in geospatial research.  In order to increase the speed of digital stereo modeling for 3D features extraction in arid area, the authors integrated Google Earth model with CMM method (GE-CMM) to investigate the possibility for environment based 3D modeling. By the research test, the GE-CMM method demonstrated reasonable accuracy and high efficient in 3D environment modeling.  This method could help scientists to restore stereo model and extract 3D GIS features in arid environment quickly.

## INTRODUCTION

The requirements of Three Dimensional (3D) geospatial features are increasing for environment related researches and applications. (Zhao Y., AlOthman A., et al, 2006; Dirk H., Markus H. et al, 2005)  It has advanced visualization effect for scientists in investigating complex environment issues with the virtual reality technology. (Kwan M-P, Lee J.,2005) However, it does not have too much 3D information in support of scientific research due to the expensive expending which should be used for 3D features collection and extraction. This situation is more difficult in arid area such as Kuwait where ground control points (GCPs) are difficult to be collected when digital photogrammetry is used for 3D features extracting.

Comprehensive Multilevel Modeling (CMM) method is apparently useful in implementing GIS modeling from national level to internal level for 3D modeling and virtual reality GIS implementation. (Zhao Y.,
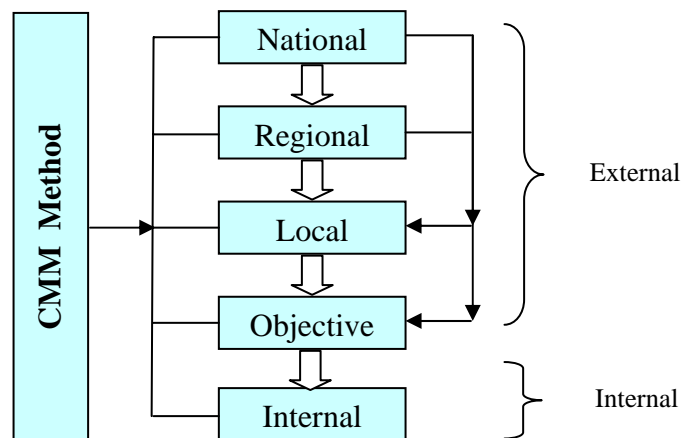


**Figure 1.**  CMM 3D and VR GIS modeling structure.

AlOthman A., et al. 2006 A). CMM was developed by the support of Kuwait 3D GIS Modeling pilot project in exploring fast establishment of 3D GIS model with less expense. (Zhao Y., AlOthman A., et al. 2006 B). It was divided into national, regional, local, objective, and internal levels to construct a national 3D and VR GIS model (Figure 1). CMM method can also be concluded as external and internal structure. The external structure includes the national, regional, local, and objective levels and the internal structure includes only internal level. This classification supplies a clear clue for users to define their 3D GIS modeling requirements and aims before start any projects.

Apparently, CMM is a method in using digital photogrammetry to establish stereo model. It has the advantage and demonstrated the high efficient in 3D GIS modeling if GCPs are possible to be collected. (Zhao Y., AlOthman A., et al. 2006 A). However, desert landform is one of the typical landscapes in arid place. It is hard to collect GCPs from the corresponding area. If this situation happened, the accuracy of digital photogrammetry stereo model would be difficult to be checked because of the lack of existed position information (GCPs). In order to deal with this normal technology problem which is existed in arid environment for 3D features extraction, Google Earth Model is integrated with CMM by the authors for 3D modeling research. It was proved as an efficient 3D GIS data extracting method for environment modeling.

## METHOLOGY ASSUMPTION

Most environment related researches are based on middle scale maps or lower resolution imagery information. Map scales such as 1:10,000 to 1:25,000 would be higher accuracy for the aims. Therefore, 3D information which is extracted from high resolution aerial photos should have enough accuracy to match this requirement.

Kuwait has collected the national color aerial photos with the resolution of 0.38 meter in the late 2003. It is a plentiful geospatial information resource for scientific research. In order to establish the national stereo imagery database with more economic and useful method, the authors integrated Google Earth model with CMM method (GE-CMM) in improving the modeling speed.

Since middle of 2005, Google has published plentiful imagery information to demonstrate global 3D features with Google Earth model. The high accuracy imagery database of Google Earth includes precisely positioning information. This is because high accuracy satellite imagery information such as Quick Bird (resolution is 2.4 to 0.6 meter) is widely used by Google Earth model. Based on this situation, it is possible to collect GCPs from Google Earth model and then use them by CMM method for environment modeling.

Based on this assumption, the imagery resolution between aerial photos and Google Earth image was compared. Figure 2A is the aerial photo snap of one permanent object in the desert of Kuwait. Figure 2B is the corresponding object in Google Earth image. Clearly the common object in the two images has similar resolution if they were used for environment analysis. The point coordinate information which is collected from Figure 2B could be exactly identified at the corresponding position in Figure 2A.
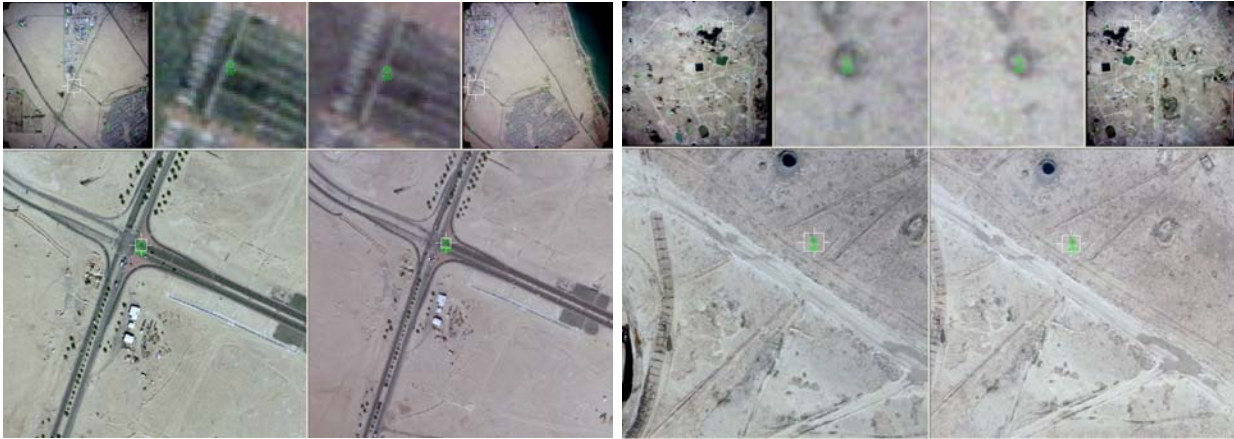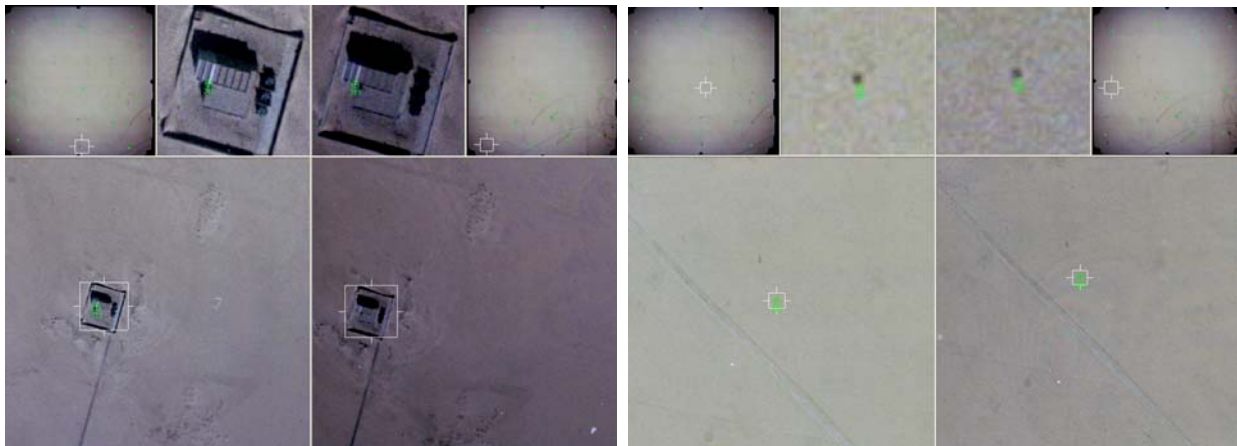


| A. Point in aerial photo | B. Corresponding point in Google Earth |

**Figure 2.** Points comparison between aerial photo and Google Earth image.

A. Desert environment mixed with residential places

B. Desert environment influenced by human activities



C. Desert environment includes fewer fixed objects

D. Desert environment without permanent objects.

**Figure 3.** Typical Desert Environment Stereo Pairs of Aerial Photos in Kuwait.

One of the important tasks of stereo modeling technology is tie points selection. As desert land is existed everywhere in arid area, it is not easy to find an exact position of one point at its stereo pairs. Figure 3 includes 4 typical desert environment stereo pairs in Kuwait. Figure A covers both residential and desert land. It is easy to find tie points in the stereo pairs by man made permanent objects. Figure B is a typical arid environment where the desert is influenced by human activities. Many temporal objects existed in the stereo pairs, so it is hard to find the exact common point in both images. Figure 3C shows a permanent object existed in desert environment which should be used as tie points. Figure 4D is a typical desert environment which includes no permanent objects. The tie point selection in the pairs is very difficult. Actually, it is hard to collect GCPs in desert environment if tie points selection is difficult.

Moreover, the scarce objects selected as tie points in stereo aerial photo pairs may be blured or blocked by mosaicked edges in Google Earth image. It also may be influenced when high resolution image could not be supplied by Google Earth model. For example, Figure 4B is a corresponding place of 4A where three images are mosaicked. They were acquired in different periods with multi-resolutions. This situation is normal for Google Earth because it is using straight lines to mosaic images and it is impossible to supply high accuracy data for all areas. If this situation is happened, the points included in the dominant image of the area may be selected as GCPs where they are closing to mosaicked edges. Figure 4C and 4D are the corresponding enlarged place of Figure 4A and 4B. The image resolution of Google Earth is still similar as that of the aerial photo. The common point in the two images could be exactly identified.

A. Point selection in aerial photo
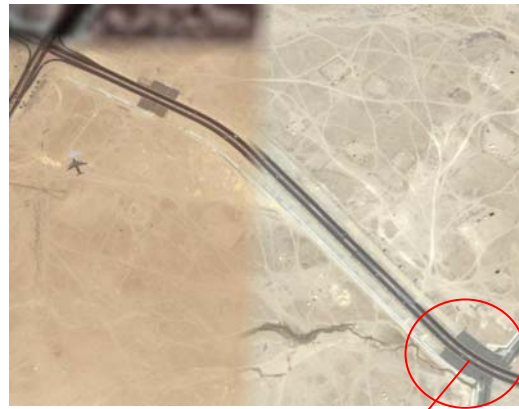
B. Corresponded points in Google Earth Image
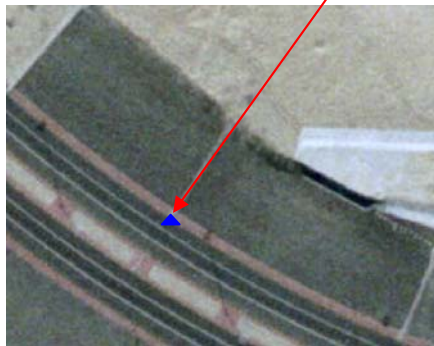
C. Enlarged point in aerial photo

D. Enlarged point in Google Earth

**Figure 4.** Comparison of Aerial Photo with Mosaicked Google Earth Image.

Based on the above analysis, it would be possible and helpful to use Google Earth model as the platform for GCPs collection.

## RESEARCH TEST

Kuwait is a small country. The total area is 17,820 km$^2$ and about 85% of it is terrestrial environment. It is connected with Saudi Arabia from south (length of the border is 222 km), Iraq from north (length of the border is 240 km), and Arabian Gulf from east (coastline is 499 km) (Figure 5). Most of Kuwait land is desert and the arable land is 0.3%. The landscape of Kuwait is nearly flat. The highest point in the country is about 306 m. Most of the residential areas are distributed along the coastline and close to Kuwait city.

In order to test the accuracy of GCPs collected from Google Earth model, a region of 500 square km in Kuwait was selected as the research area (Region A in Figure 5). 63 aerial photos were included for the research test. The experimental area covers the typical desert dominated landscape in Kuwait such as ocean and urban, ocean and desert, urban and desert, and pure desert areas were included in the model.

The test is finished in four steps. The first step is to establish the stereo model by digital photogrammetry technology where 1008 tie points and 19 check points were collected for the stereo modeling. (Figure 6) The second step is to correct the stereo model by entering 35 GCPs collected by GPS machine (Figure 7). The third step was to replace the coordinates of the 35 GCPs with the corresponding value collected from Google Earth model. The fourth step was to extract the 3D features in one experimental area (Figure 8) from each of the three stereo models and then test the relative elevation information of the models by the true value acquired with TPS machine.

**Figure 5.** Map of Kuwait. (A is the research.).



**Figure 6.** Tie points.



**Figure 7.** GCPs in the test area.



**Figure 8.** 3D features in the selected area.

As the result, the original stereo model was established by the input of the existed interior orientation parameters, the coordinates of exterior orientation, and the selected 1008 tie points. After finished the bundle block triangulation adjustment, the model still includes an absolute height error for more than 20 meters and the planar error around 10 meters.

After the 35 GCPs collected with GPS were input to the original model, the model accuracy increased. Both the absolute height and planar error decreased to 1 meter.

After the 35 GCPs collected from Google Earth model were input to the original model, the model accuracy improved. Both the absolute height and planar error decreased around 10 meters.

In contrasted to the absolute height errors, the relative height errors are very small in the models. By comparing of the buildings' relative height (relative height = roof – bottom), the average height error is below 1 meter in the corresponded models.

| A. Virtual reality modeling | B. Engineering computation |

**Figure 9.** Applications of the image database.

## DISCUSSION

Digital photogrammetry stereo modeling technology was original created in improving the efficient of survey and creating large scale maps. By the development of computer technology, the expense used for digital photogrammetry has been decreased dramatically in comparing with traditional photogrammetry technology. Anyhow, it is hard to conduct stereo modeling with digital photogrammetry technology and check the model accuracy if without GCPs.

GE-CMM method is using Google Earth high accuracy positioning information as GCPs to improve digital photogrammetry modeling accuracy which is used by CMM method for imagery database design and 3D features extraction. The accuracy of GCPs is allowed for 3D environment modeling requirement based on the authors test. The change of this mind would improve digital photogrammetry modeling speed and could increase the 3D features extraction dramatically.

Figure 9 is an example 3D model established based on the support of GCPs collected from Google Earth model. As the planar and the relative height accuracy is required by the engineering project, the 3D model is good enough in computing the engineering related computation such as land volume measure etc.

Of course, the accuracy of GE-CMM method which is used for 3D modeling was only tested in the selected area. Further test about the accuracy should be done in order to expanding the method for stereo modeling in the west desert of Kuwait.

## ACKNOWLEDGEMENTS

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