Integration of 3D Geospatial Information for Radar Viewshed Analysis of Urban Warfare Simulation

Ming-Da Tsai[1*] and Peng-Wen Lai[2]

[1]*Environmental Information and Engineering Dept., Chung Cheng Institute of Technology, National Defense University*
[2]*Institute of Electrical and Control Engineering, National Chiao Tung University*

ABSTRACT

The booming economy and the advance of society lead to densely populated settlements of towns and cities in Taiwan, and some of these towns and cities have been developed into very important centers of local politics, economy, culture and transportation. The occupation or defense of these urban settings has profound impact to the overall warfare in times of war. Modern buildings are structurally fortified and strengthened. High-rise buildings are next to one another. These buildings can be integrated into a strong defense system if troops and fire power are arranged properly. Therefore, the "urban warfare" has become one of very important patterns of warfare in the defense of Taiwan and Penghu. Geospatial information of terrains and radar viewshed analysis were combined for this study, with the simulation of the 3D building barrier and ground radar field of vision, to simulate the battlefield environment of urban operations.

Keywords: Urban Warfare, Geospatial Information, Radar Viewshed Analysis, Simulation

整合 3 維空間資訊於城鎮作戰模擬之雷達視域分析

蔡明達 [1*]　賴鵬文 [2]

[1] 國防大學理工學院環境資訊及工程學系
[2] 國立交通大學電機學院

摘　　要

隨著社會經濟蓬勃發展，臺灣本島城鎮密集且多為政治、經濟、文化及交通的中心，其攻佔或固守，對整體作戰有長遠之影響；現代化建物強固堅韌、高樓鱗比節次，如善加運用適切兵力、火力可成為堅強之防禦體系，故「城鎮戰」已成為未來臺澎防衛作戰中重要作戰型態。本研究結合地形地物之空間資訊與雷達視域分析，藉由仿真的 3D 建物屏障以及地面雷達的視域，來模擬城鎮作戰之戰場環境。

關鍵字: 城鎮戰、空間資訊、雷達視域分析、模擬

文稿收件日期 106.10.2;文稿修正後接受日期 107.2.27; *通訊作者
Manuscript received October 2, 2017; revised February 27, 2018; * Corresponding author

I. INTRODUCTION

The western part of Taiwan is mostly flat and densely populated (as shown in Fig.1). Decades of development has resulted in significant urbanization as we see today. This indicates that the "urban warfare" has a very important part in the study of land-based warfare. The US military has learned from the numerous combats in urban settings ever since the 1940s that the urban warfare features a number of characteristics unlike other types of warfare, including complicated preparation works for battlefield intelligence, difficulties in battle planning, complexity of command and control, limited room for maneuver of troops in a mobile manner, serious concern of fire power demonstration, and challenging supplies and maintenance. In an urban setting, roads and streets crisscross among high and low buildings. The topographic features that are complicated and easy to shelter and hide in are often a headache to commanders at all levels when it comes to having access to enemy intelligence [1].

Military exercise is a method and means of training that enables commanders and their staff to be familiar with a battlefield environment. However, limitations, such as the overall external environment, public opinions, training grounds, safety of exercise, possible loss of weapons and equipment, and huge training budgets, have prevented live exercises where large scale of forces are involved and which are necessary to maintain the quality and quantity of military training[2]. In response to the dilemma of "three highs and one difficulty" (that is, "high value," "high risk," "high energy consumption" and "difficulty in sourcing for a proper training ground") in training, the Armed Force of Taiwan is currently seeking out ways to replace "live exercise" with "computerized wargame" in order to work around the limitation of training facilities. The use of computer simulation technology in exercise and training of troops of all levels, analysis and planning of deployment of force in battlefield, as well as the development of national strategies has become a trend of military technology development around the world. One that is most widely used in the world is "computerized wargame system" [3] in combination with the use of results derived from battle simulation analysis.

Fig.1 Most of the population in Taiwan is concentrated in the western part of the island where the terrains are flat (the red areas shown in the picture are buildings)

The analytic models that are current deployed in the Armed Force of Taiwan are the "Integrated Theater Engagement Model (ITEM)" and the "Extended Air Defense Simulation (EADSIM)." However, the influence of buildings on combat effectiveness is not taken into consideration for either of these two models. It is impossible to have a thorough characterization and analysis on the information of urban space where it is complicated in nature and easy to shelter and hide in.

1.1 Integrated Theater Engagement Model (ITEM)

ITEM is a high level model with low solution that allows simulation of engagement in land-based environment, naval settings (on the surface, under water and amphibious), air space and missiles. It is an analysis model at the integrated battle level that is focused on joint combat. It provides comparison of various types of (joint) combat action solutions, combat schedule and combat effectiveness analysis. As a result, ITEM is used mostly for high level federations with low solution. The primary types of spatial data are land and sea (or water). The analysis on terrains and topography is rather limited. The simulation is based on the mathematic models of ultimate federated engagements, and digital topographic information has no influence, as shown in Fig.2.

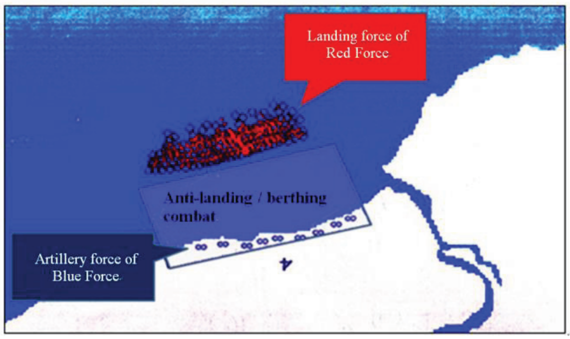

Fig.2 A scheme of computerized wargame using ITEM

1.2 Extended Air Defense SIMulation (EADSIM)

EADSIM is a mission level model with high solution. Commonly used for combat study and analysis in relation to air defense, space warfare and missile defense, EADSIM is capable of simulating "single platform engagement," "multiple force engagement" and "theater level" warfare. It is equipped to provide overall combat planning, training and analysis for combatants. It consists of several sub-models, including air warfare, space warfare, electronic warfare, command / control / communication / intelligence and missile defense [4].

When it comes to the processing and analysis of battlefield environment, EADSIM is able to read ADRG (ARC Digital Raster Graphics) in NIMA (National Imagery and Mapping Agency) format, CADRG (Compressed ARC Digital Raster Graphics), CIB (Controlled Image Base), image files and topographic data such as Digital Terrain Elevation Data (DTED). These data allow for the sideview profile analysis in addition to search and calculation of location and distance in general. As shown in the following figures, Fig.3 (a) is an example of how the display of Extended Air Defense Simulation looks like. The model provides tools for sideview profile analysis, and the result is shown in Fig.3 (b). In addition, this model allows the analysis of effective detection range of sensors. EADSIM considers the shielding influence of ups and downs in topographic elevation on sensors, as shown in Fig.4. In Fig. 4(b), the white lines are detection lines at the elevation of 3000m, whereas the cyan lines are those at the elevation of 500m. The cyan lines are more susceptible to terrains since they are closer to ground. As for white lines, the blind zone of radar is larger. For weapon platforms, the settings of movement must take into consideration the influence of terrains. However for topographic features (such as buildings, electric towers, chimneys and trees), the topographic feature simulation is not included due to the limits in the calculation of digital elevations in high resolution. It is unable to satisfy the need for the environment analysis of a battlefield space as densely urbanized as the island of Taiwan.

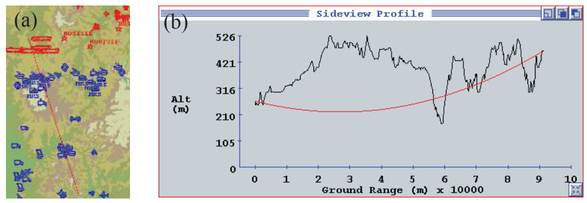

Fig.3 (a) It is allowed to use the sideview profiling tool in the EADSIM window and perform analysis along the red line; (b) display of sideview profiling data

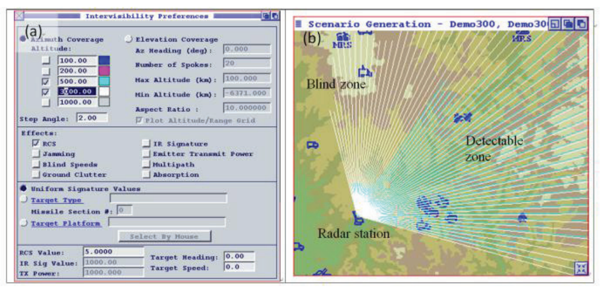

Fig.4 (a) This is the setting window for the reference of sensors' effective detection range; (b) this shows the effective detection range of a sensor, where the white lines and cyan lines represent the detection lines at the elevations of 3000m and 500m, respectively

At present, most of countries around the world are facing a number of difficulties, including military staff downsizing, shrinking size of battle exercises and training grounds, and training expenses too expensive to afford. However, the maturity of various types of modeling and simulation systems facilitates the use of computer simulation in the aid of battle training of military forces, analysis and planning of battlefield force deployment and the strategic goals of country at the moment. The spatial information is put together and life-like battlefield environment is established to improve the operations of modeling and simulation. It is now a trend in most of the countries in terms of military technologies.

1.3 3-dimensional modeling

The 3-dimensional modeling is a process in which a 3D digital city is divided into 5 levels of detail (LODs) [5] using the City Geography Markup Language (CityGML) that was developed by the Open Geospatial Consortium (OGC), as shown in Fig.5. The LODs are listed as follows and shown in Fig. 5 below: (1) LOD0: this level covers only the topography and overlapping of different layers of theme and provides 2.5D display; (2) LOD1: at this level, buildings that look like toy building blocks (without roof types) are added on topography. This level is applicable to regional or city scale; (3) LOD3: roof structure types and wall finishing textures are added at this level, which is at the scale of architectural models; (4) LOD3: this level consists of models of attachments on roof and walls at the scale of architectural models; (5) LOD4: this includes the models of building interior, which provides an architectural model with walkable details.

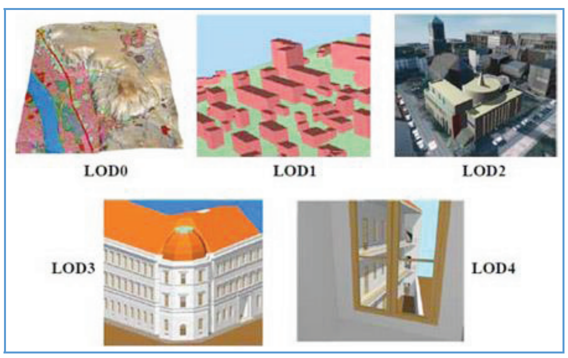

Fig.5 The 5 levels of detail (LODs) in CityGML [5]

1.4 Introduction to STK program

Developed by AGI (Analytical Graphics, Inc.), the STK (System Tool Kit) program (as shown in Fig.6) is a state of the art program for simulation and analysis for space and national defense missions. It analyzes the relative position and orientation of a vehicle on land, at sea, in the sky and in the vast space. It is capable of simulating and calculating communications, remote sensing and radar payloads, and integrating the entire scenario in 4D visual animation [6].

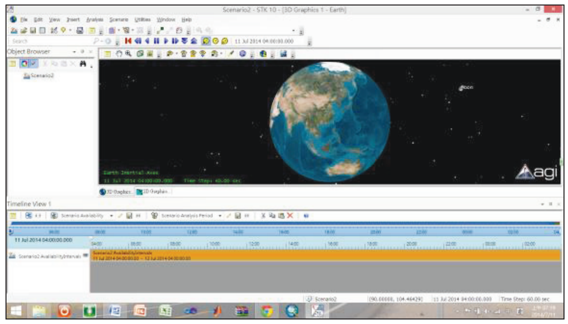

Fig.6 Interface of the simulation and analysis program, STK

Some examples of the common applications of STK are: automatic warning of satellite detection and photographing, automatic interception of ballistic missiles, 4D flight simulator in a war game, and anti-radar / missile jamming. It is equipped to interface with geographic information system (GIS) and combine with the spatial data of the atmospheric environment for various capabilities of simulation and analysis. For spatial data, it is compatible with ESRI (Arc GIS), Google Earth and Microsoft Virtual Earth, and CADRG, JPEG2000, CIB, GeoTIFF and NITF for image. For elevation data, it reads DTED and DEM. For atmospheric environment data, STK provides the atmosphere model. For the analysis of rain attenuation estimation, it provides the rain attenuation model developed by Crane, R. K. (1978) and the rain attenuation model of International Telecommunication Union (ITU-R P838 1992). STK is capable of analyzing and studying 3D terrain data and often used in satellite projects, space science, research and development of military equipment, space intelligence, exercise and training of military forces, wargame, and combat simulation and analysis.

II. Data Collection and Processing

The Yuan Shu Lin area of Daxi, Taiyuan was selected as the experiment area, as shown in Fig.7 below. Topographic surveying and plotting and 3D modeling of buildings on the ground were performed on this area using various surveying techniques in order to establish the spatial information of this area for the simulation and testing in STK.

Fig.7 Aerial photo of Yuan Shu Lin, Daxi, Taoyuan, which is the selected experiment area

2.1 3D modeling of the experiment area

The acquisition of Geospatial data in the experiment area and the process of 3D building modeling are provided in Fig.8. The first step started by measuring the terrains in a large area using aerial (or remote) sensing techniques with the aid of the precision positioning data obtained from the global positioning system (GPS). Thus, the topography of the experiment area and its coordinates were determined. Next, the 3D topographic model was built to gain he access the elevation data of terrains and geographic features. Finally, 3D modeling was performed on the buildings.

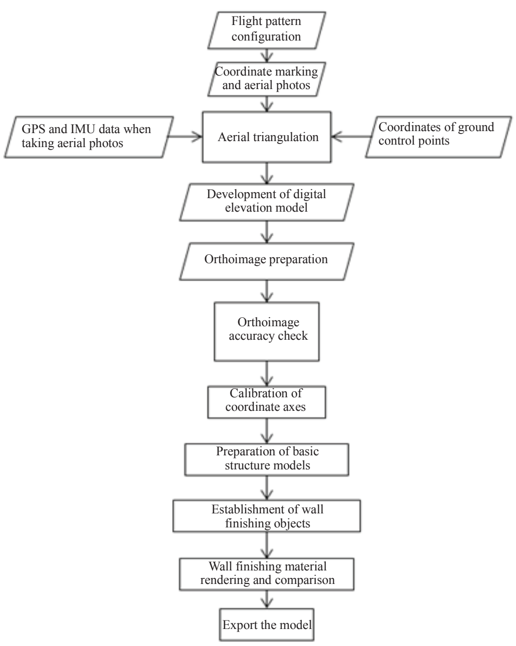

Fig.8 Acquisition of Geospatial data in the experiment area and the process of 3D building modeling

2.2 Surveying of the experiment area

1. Flight pattern configuration for unmanned aerial vehicle

The Yuan Shu Lin area at Daxi, Taoyuan was selected as the experiment area. The flight patter configuration program, eMotion2, was used to develop a flight pattern for the aerial photography. Two flight patterns were developed for the unmanned aerial vehicle used. The first was with Chung Cheng Institute of Technology in it (as shown in Fig.9 (a)). The aerial photo flight was taken in July 2013 at an elevation of 200m above ground. The other flight pattern included Daxi. The flight was taken in October 2013 at an elevation of 130m above ground (as shown in Fig.9 (b)). The forward overlap of the aerial photos taken in both the flights was 70% and the lateral overlap was 60%. The size of single frame was 4,608 pixels x 3,456 pixels for all photos taken.

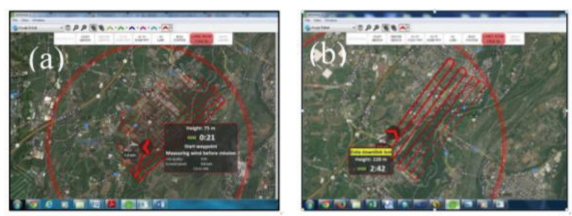

Fig.9 Flight patterns for (a) Chung Cheng Institute of Technology and (b) Daxi

(1) Surveying of ground control point coordinates and elevation data

The data processing came after the aerial photo flights of UAV were completed. The ground control points were added and aerotriangulation procedure was performed. The ground control point coordinates were measured using e-GPS. 3 points and 6 points were selected in the surveying areas as the control points. The surveyings were taken every second and more than 60 surveyings were received for both flights. The "electronic global satellite real-time kinematic positioning system (the e-GPS real-time kinematic positioning system or just e-GPS) was developed by National Land Surveying and Mapping Center, Ministry of the Interior in 2004 using the technique called "Virtual Base

Station Real-Time Kinematic" (VBS-RTK) [4]. The working principle of Unmanned Aerial Vehicle (network-based GPS real-time positioning system) is that the RTK station is located on a ground control point to receive signals from satellite positioning base stations established throughout Taiwan and evaluate the positioning errors in the areas covered by these base stations. With the observation data from the nearest physical base station, the RTK is considered a virtual base station with which to identify its coordinates and elevation, and finally, the orthometric height is obtained through the direct leveling in elevation (National Land Surveying and Mapping Center, Ministry of the Interior, 2007)

As the aerotriangulation procedure was finished, the outer orientation parameter of every UAV photo and orthoimage mosaic of the surveying areas were decoded and the orthoimages with geographic positioning coordinates went through the planar precision test. The test points were determined using e-GPS, and the root mean square error (RMSE) was calculated. The orthoimage tested was imported into the UAV 3D image platform developed, which allows the comparison between images in two windows or image overlapping analysis in a single window. Also available is the simple surveying and analysis functions.

(2) Setting up ground control points

The purpose to set up ground control points was to allow the interconnection between aerial image data and the coordinate data in real space. In the old days, navigation marks had to be set up in the surveying area when performing aerial photo surveying as the ground control points to improve accuracy of aerial photo surveying. However, thanks to the global positioning system (GPS) on board of UAV, the coordinates of aerial images are easily obtained. In order to determine the influence of number of ground control points on the positioning accuracy, three different numbers of ground control points were selected for both the surveying areas (as shown in Tab.1). One of the reasons was to prevent errors resulted from different ground control points selected. For 6 ground control points, there had to be the positions of 3 ground control points in that area.

Tab.1 Number of control points

<table>
<tr><td></td><td>CCIT</td><td>BM3</td></tr>
<tr><td rowspan="3">No. of ground control points (GCP)</td><td colspan="2">No ground control point</td></tr>
<tr><td colspan="2">3 control points</td></tr>
<tr><td colspan="2">6 control points</td></tr>
</table>

(3) Preparation of UAV orthoimages

The image data from the aerial photos taken by UAV were imported into Postflight Terra 3D-EB along with the coordinates and elevations of ground control points. The projection coordinate of 121 degree zone in Taiwan Datum 1997 was selected for calculation of 3 different numbers of ground control points described in Table 1. Hence the point cloud of images and individual orthoimages were obtained. Then, the orthoimage of the entire area is achieved with matching and color rendering (as shown in Fig. 10 (a) and (b)).

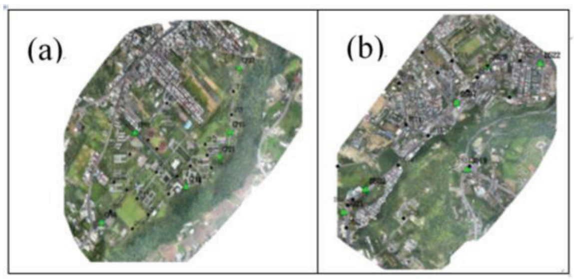

Fig.10 Plot maps for UAV control points and check points at (a) Chung Cheng Institute of Technology and (b) Daxi (: control point; : check point)

2. UAV orthoimages

The images from UAV aerial photos were added with ground control points for AT adjustment and the orthoimages with geographic positioning were overlapped on Google Map (as shown in Fig.11 (a) (b)). It is easy to tell the difference in accuracy between the UAV orthoimage and Google Map with naked eyes, and the color tone of UAV orthoimage is closer to the real terrains.

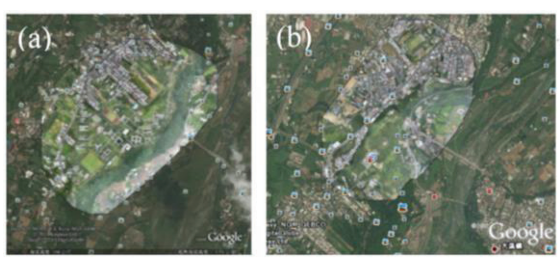

Fig.11 Othroimages of (a) Chung Cheng

Institute of Technology and (b) Daxi overlapped on Google Map

3. Accuracy check

The root mean square error (RMSE) is commonly used for position accuracy in accuracy check. The root mean square error is a type of standard deviation in a wider sense. It works by calculating the square root of the mean square error (MSE) of the different at point *i* in either the x or y direction (ΔXi, ΔYi) on the coordinate where the check point on the image checked and the coordinate of the check point on another image data with greater accuracy. It works for checking multiple different physical surveyings, such as the root mean square errors of a check point group (RMSEx, RMSEy) and planar root mean square error (RMSEr), in order to have a clear picture of the less accurate indicator between the two sets of coordinates:

$$RMSE_X = \sqrt{\sum \frac{(X_{data,i} - X_{check,i})^2}{n}} = \sqrt{\frac{1}{n}\sum \Delta Xi^2}$$

$$RMSE_Y = \sqrt{\sum \frac{(Y_{data,i} - Y_{check,i})^2}{n}} = \sqrt{\frac{1}{n}\sum \Delta Yi^2}$$

$$RMSE_r = \sqrt{RMSE_X{}^2 + RMSE_Y{}^2}$$

where,

ΔX_i is the difference of check point i in the X direction coordinate;

ΔY_i is the difference of check point i in the Y direction coordinate;

n is the total number of check points;

$X_{data,i}$ and $Y_{data,i}$ are the coordinates of check point i in the map image to be checked; and

$X_{check,i}$ and $Y_{check,i}$ are the reference coordinates of check point i.

7 check points were selected for this study. Surveyings were made with e-GPS at one surveying every second. More than 60 surveyings were made for each of the points. Another comparison was made between the orthoimages prepared with and without ground control points in the calculation of AT adjustment. The root mean square errors (RMSEs) of the coordinates of check points in the image and the ones from the actual surveyings are shown in Tab.2 to 4. The relationship between the number of GCPs and RMSE is provided in Fig. 12.

When there was no ground control point, the positioning was accurate to 4m for CCIT and 2m for Daxi. When three ground control points were added, the positioning was accurate to 0.7m for CCIT and 0.2m for Daxi. When six ground control points were added, the accuracy improved to 0.3m for CCIT and 0.1m for Daxi.

Tab.2 RMSEs of check points (without ground control point), in m

Area	X dir.	Y dir.	Planar
CCIT	±2.84278	±2.78318	±3.97838
Daxi	±0.49741	±1.81958	±1.88634

Tab.3 RMSEs of check points (with three ground control points), in m

Area	X dir.	Y dir.	Planar
CCIT	±0.63055	±0.24234	±0.67552
Daxi	±0.12474	±0.10295	±0.16174

Tab.4 RMSEs of check points (`with six ground control points), in m

Area	X dir.	Y dir.	Planar
CCIT	±0.26352	±0.11600	±0.28792
Daxi	±0.08387	±0.04103	±0.09337

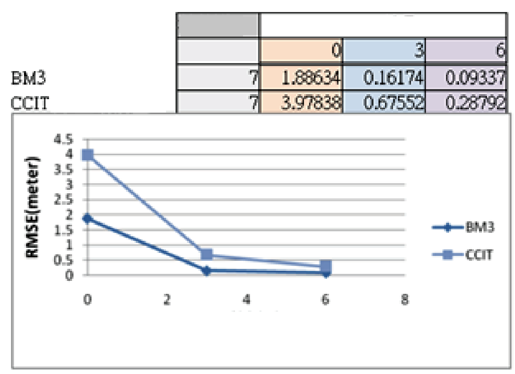

Fig.12 Number of GCPs vs. RMSE for CCIT and Daxi

2.3 Development of 3D building models

1. Calibration of coordinate axes

When it comes to the 3D building model construction, the modeling criteria of LOD3 was adopted for the establishment of building models in the experiment area. The first step to build a model was to recalibrate the coordinate axes. The Google Map functions included in Sketch Up were introduced to convert the satellite images of buildings into background image. The corners of building were used to define new coordinate axes. There was a very visible difference in establishing the contour of a building before calibration (as shown in Fig. 13(a)) and after calibration (as shown in Fig. 13 (b)) for particularly buildings with a simpler shape or structure (similar to, for example, a rectangle). It was much easier to refine the details after recalibrating the coordinate axes. However, if dealing with a building that is complex (a building with an irregular shape such as the Armament Building), the orthorimages of UAV helped characterize a more accurate frame.

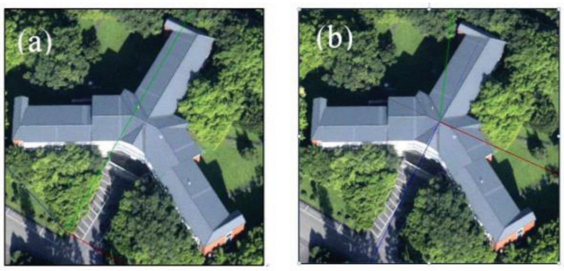

Fig.13 A building (a) before calibration and (b) after calibration

2. Preparation of basic structure models

The orthoimages produced by UAV were used to characterize the contour of building and define the length and width of building. Then, LiDAR, or Light Detection and Ranging, was introduced for its advantages of rapid observation, high accuracy and the ability to observe terrains and objects on the ground at the same time. The use of data from LiDAR observation allowed the development of multiple digital topographic models. In general, these models were Digital Elevation Modeling (DEM), Digital Terrain Modeling (DTM), Digital Surface Modeling (DSM) and Digital Building Model (DBM). By subtracting DEM from DSM, the elevation of building was obtained, and then the basic structure model of building was achieved (as shown in Fig.14) [7,8]

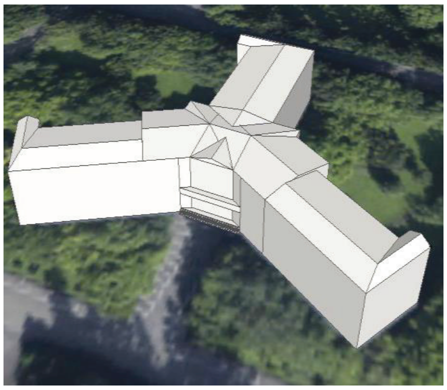

Fig.14 Basic structure model of building

3. Establishment of wall surface objects

The photos of various walls were taken on site. These photos were taken to cover all four corners of the walls (as shown in Fig. 15) in order to identify the positions of objects on the wall, such as eaves, windows, stairs, and so on. Once the positions were identified, the wall objects were plotted to finish the object refinement of building details.

Fig.15 Position of objects

4. Wall finishing material rendering

There are always unwanted objects when taking the photos of walls, such as people, cars, trees and anything that would obscure the look of building (as shown in Fig.16). If it is impossible to avoid objects that cover part of the wall, the Sketch Up has the “Set as the only texture” function for help. Since the walls to be taken photos of were covered mostly with ceramic tiles, which are the same texture over and over again, the only thing to do was to identify the repetitive unit texture (as shown in Fig.17) and the rest was to use this texture to cover the objects that obscured the wall and piece together the entire surface of wall. As shown in Fig.18, (a) Before the obscuring objects were removed and (b) after they were removed.

Fig.16 Example of objects that obscured a building

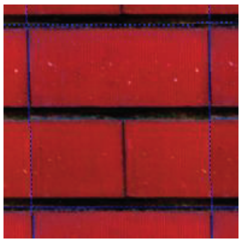

Fig.17 Unit texture of wall surface

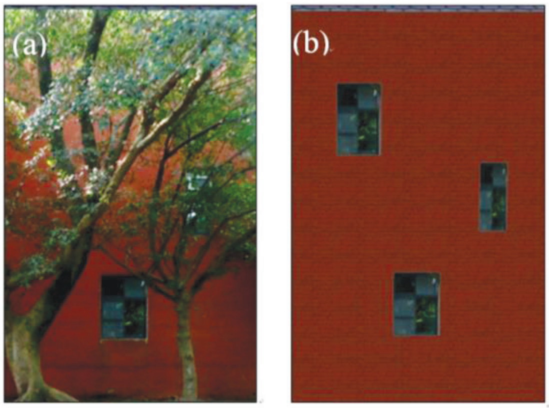

Fig.18 (a) Before the obscuring objects were removed and (b) after they were removed

5. Exporting the models

Once developed, the building models were exported in .dae format to allow STK and other programs to load these various refined models at LOD3. When importing these models into the interface of STK or other programs, it will be easier to import these data. The result of models is shown in Fig.19.

Fig.19 Result of models

III. Simulation Scenario Design and 4D Simulation Data Processing

3.1 Loading 3-dimensional geospatial data

The Yuan Shu Lin area of the township of Daxi was selected as the experiment area. The surveying was made possible by Geo-spatial information technology and the 3D map of the selected area was developed. The result was the topographic map of the area and 3D models of buildings in this area. The STK program used for this study is capable of reading spatial information in various formats, including: JPEG2000, BMP, PNG, TIF, Shape File, DTED (*.dtd,*.dt0, *.dt1, *.dt2, *.dt3, *.dt4, *.dt5, *.dt6), pdtt, pdttx, kml, and kmz. For 3D building models, it is capable of reading formats such as mdl and dae.

For the elevation data of the terrains, high resolution digital elevation model (DEM) was obtained through LiDAR or aerial photos. The data were later converted into DTED format. The 3D models of building were developed using the refined modeling specifications at the LOD3 level. The prepared building objects were exported into files in mdl and dae formats, which were imported into STK. The procedure to import spatial data is described as follows: firstly the coordinate positions of the experiment area were established and the image files from aerial (satellite) photos of that area were imported. Then, the DTED elevation data were imported. Finally, the 3D building objects were imported. At this moment, the building objects were placed and positioned by hand based on the locations shown on the aerial (satellite) photos, as shown in Fig.20.

Fig.20 Importing the 3D building objects developed into system

3.2 Scenario design

The design of scenario, as shown in Fig.21, was tested to see whether topographic features (or buildings) have any impact on the detection viewshed when radar is detecting an object. An air defense radar station was established among the buildings in the experiment area. A general helicopter was added to hover around the radar station at 100 nautical miles per hour. This setup was to determine whether the radar viewshed was compromised due to the shielding effect of buildings. Fig.21 shows the detection range of the radar station. For the purpose of this study, the radius of the radar's detection range was defined at 3km. The range and distance of the yellow dome shown in the figure indicates the viewshed in which the radar is effective in detection. As shown in Fig.22, the rugged base of the yellow dome indicates the impacts created by the shielding of topographic features and buildings. It is clear in Fig.23 that a radar blind spot was created at the area behind the building shown, which is the result of compromised detection range of radar due to the shielding impact of building.

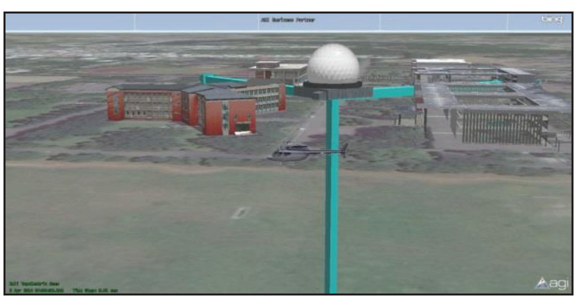

Fig.21 The radar station was designed among several buildings to test the impact of buildings on the radar's ability to detect

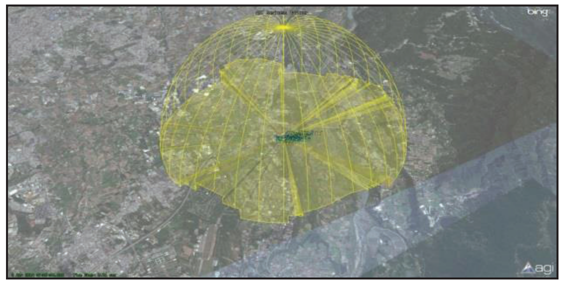

Fig.22 The detection range of air defense radar

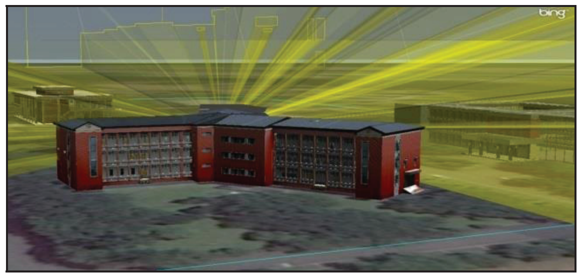

Fig.23 The radar detection blind spot (blind zone) was created behind the building in the figure due to the shielding effect of building

IV. Result Display and Analysis

In Fig.24, the window on the top is a 3D simulation scenario. For this study, the radar station was located between 4 buildings. A helicopter took off from the lawn next to the radar station and hovered around the station. The time series was shown in the window at the bottom. The red section of line meant that the helicopter was detected by the radar in this particular period of time (4D simulation was achieved by adding the element of time). When the helicopter was picked up by the radar station, a yellow line of detection connected the radar station and the hovering helicopter as shown in the window on the top. The yellow area was the detectable zones of the radar, whereas the rest was the radar's blind zones.

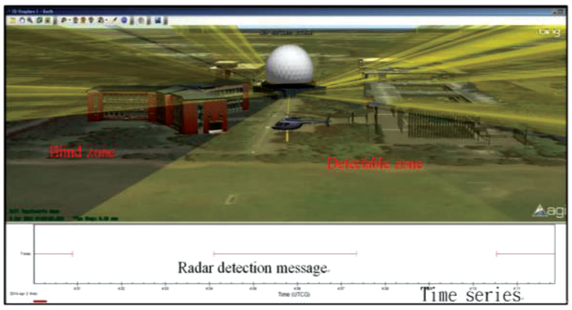

Fig.24 Description of simulation display

The helicopter took off at minute 4 and flew out of the detection range of the radar at minute 4.01 and then back in the detection range of the radar at minute 4.04. It hovered around the radar station to test the influence of the buildings on the ground on the detection ability of radar. When the radar detected the helicopter, a detection line of radar was generated in the 4D simulation scenario. If not, the detection line between the radar and the hovering helicopter disappeared, as shown in Fig.25. The helicopter hovered for 12 minutes. Fig.26 showed the trajectory of the helicopter at minute 11, which indicates that the helicopter was within the detection range of the radar and therefore detected by the radar.

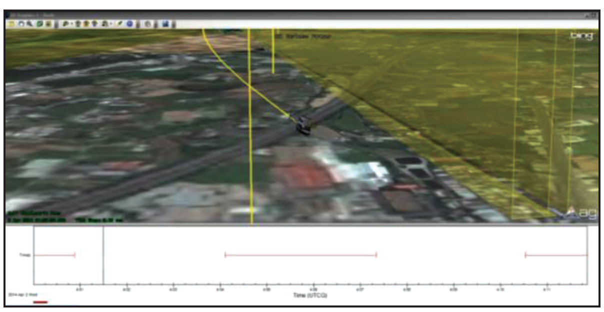

Fig.25 The detection line between the radar and the helicopter disappeared when the helicopter flew out of the detection range of radar

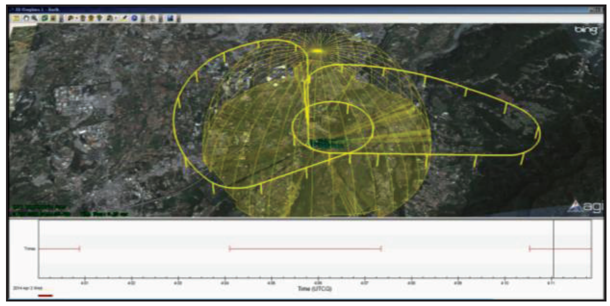

Fig.26 The flight trajectory of helicopter hovering around the radar station

V. Conclusions and Suggestions

5.1 Conclusions

Sun Tzu, the author of the Art of War, once said: “The natural formation of the country is the soldier's best ally.” Similarly, western military scientists said: “map is the eyes and ears of a military force.” This is just to show how important a clear map is for troops in a battle. Everything from the development of combat plan to the basics of command and control depends on it. Commanders and their staff acquire the information of terrain intelligence in maps for coordination and communications in federated combat maneuvers and space coordination of tri-force jointed warfare [9]. As a result, the decision on national defense and security, command and control in war time and everything military are built upon the correct knowledge and judgment about the space in which combats take place. The military exercise and training with the aid of computerized war gaming and modeling and simulation analysis is one of the best methods and means to train commanders and their staff to familiarize themselves with the environment of possible battlefield.

At present, the Armed Force of Taiwan is still working on integrating spatial information (topographic features in particular) models into tools used for simulations of urban combat in high resolution, including model analysis program currently employed in the Armed Force, such as Extended Air Defense Simulation (EADSIM), Integrated Theater Engagement

Model (ITEM) and the Synthetic Theater Operation Research Model (STORM) that will soon to be introduced. It is found in the results of this study that the detection zone of radar is susceptible to terrains and topographic features and therefore blind spots or blind zones are created for the radar. A helicopter is very likely to be detected when it flies into the detection range of radar. However, the shielding and covering of buildings help the helicopter stay out of the radar detection. As a result, a realistic 3-dimensional battlefield was created for this study. With the careful setup of the simulation scenario (i.e. the detection range of radar and simulated flight patterns of helicopter), it is much easier to develop the knowledge about the environment of a battlefield in real life.

Thanks to the advance in the development of geo-spatial information technology, the surveying of terrains and topographic features was improved more effectively by employing unmanned aerial vehicle (UAV) in combination with spatial surveying instruments such as remote sensing (RS), global positioning system (GPS) and inertia navigation system (or IMU), and it is now much quicker and more accurate to acquire spatial information on the surface of Earth. The surveying was performed in three different conditions for this study. For the assessment and analysis of accuracy, the positioning was accurate to 2 to 4m with no ground control point. If three ground control points were added, the positioning was accurate to 1m or less; and finally, if six ground control points were added, the coordinate positioning was more accurate to 0.5m or less. These levels of accuracy were enough to satisfy the need for information of space at the time of simulation. In terms of timeliness, this study showed that it took approximately a work day to finish the entire process from the onset of aerial photography to the acquisition of the orthoimages needed with ground control points. However, it took longer to establish the models of topographic features as the building models developed for this study were refined ones at LOD3 level. It took 5 work days in average to build the model of a building. This was exactly the reason why no more than 8 building objects were loaded for the simulation test described in the study because of the inherent limits in the performance of the computers used (as shown in Fig.27).

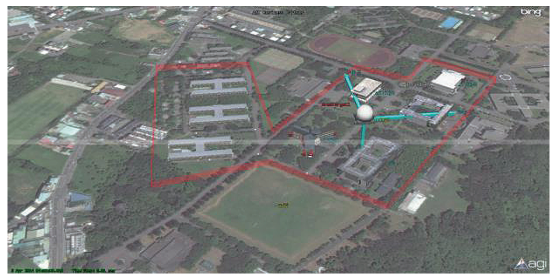

Fig.27 8 building objects were imported in the area enclosed by the red lines

5.2 Future development and suggestions

The knowledge about and attention to the environment of a battlefield was limited only on terrains in the past, and topographic features were usually neglected. If the terrains and topographic features are displayed in 3D in the future in military intelligence gathering and establishment or in exercises, training events or war games, it will be able to improve the perception of commanders or staff about the "battlefield space." The addition of time in exercise or training simulation makes the 4D simulations possible. For example, as shown in Fig.28, the coastal areas of Tamsui are riddled with ocean view buildings, which are possible hiding places for attack or reconnaissance helicopters to prevent enemy detection. In Fig.28, the green parts are detectable zones for the radars of red force, while the red zones are the blind zones of radar. In Fig.29, helicopters may hide in the radar blind zones created by the buildings from enemy radars. Apart from this, such simulation can be sued for prevention of potential flight accidents. For example, April 3 2007, an Army UH-1H crashed into the transmission tower of a radio transmission station of the Police Radio in the Zhongliao Mountains at Qishan, Kaohsiung. The helicopter went down with all 8 soldiers and officers killed. The major reason for this disastrous accident was that the flight crew was unfamiliar with the local terrains and topographic features. It is a future possibility to deploy UAVs to scan the topography for spatial information surveyings and simulation and analysis of disaster rescue routes. It can come in handy when the Armed Force is trying to develop a rescue plan and perform effectiveness simulation of air defense position deployment using 3D military map intelligence.

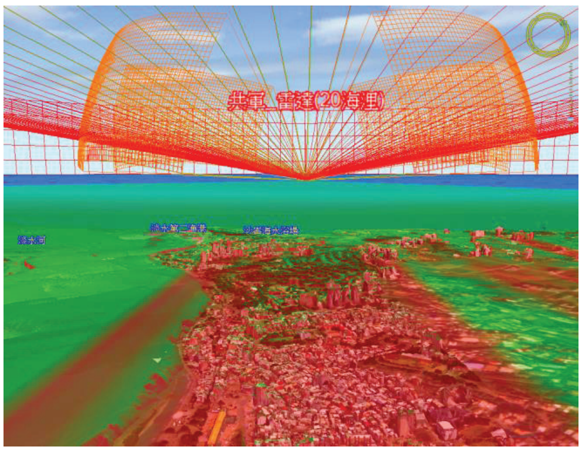

Fig.28 The green parts were the detectable zones for the radar of red force, whereas the red zones were the blind zones of radar


Fig.29 Topographic features provide hiding places for helicopter

The building models developed by this study were based on the specifications of refined modeling at LOD3. Therefore, the files of these objects were so big that the computer performance was unable to meet the requirement. If a model of a city is to be built in this way, it could be a challenge for computer wargame or modeling and simulation analysis. Hence, it is suggested to develop large scope of 3D models with LOD1 or LOD2 specifications (as shown in Fig.30) in order to reduce the size of 3D object files and improve the performance of simulation systems.


Fig.30 Specifications of 3D town at LOD2

Acknowledgement

The study group would like to appreciate AGI for providing the STK program for trial and their assistance, and Dataforce for providing technical supports that were vital to make this study possible.

References

[1]Guang-Jiang Pang, "The Tactics of The Urban Warfare in US. Army and Its Enlightenment to Us", Infantry Magazine Quarterly, No. 219, 2005. (in Chinese)
[2]Cun-Zhou Lai, "The Study on the Troops Training with War-game Simulation - Taking JCATS as an Example", Army Bimonthly, Vol. 49, No.530, pp.4-22, 2013. (in Chinese)
[3]Chuan-Wei Chiang, "The Study of Terrain Files for Joint Conflict and Tactical Simulation", Master Thesis, Chung Cheng Institute of Technology, National Defense University, Taoyuan, Taiwan, ROC, 2012. (in Chinese)
[4]The Modeling and Simulation Office, Department of Integrated Assessments of MOD.,"2008 EADSIM Analyze Training Handouts", Taipei, ROC., 2008. (in Chinese)
[5]Gröger, G., T.H. Kolbe, A. Czerwinski and C.

Nagel, 2008. OpenGIS City Geography Markup Language (CityGML) Encoding Standard, OGC-08-007r1, v. 1.0.0, Open Geospatial Consortium Inc., URL: http://www.opengeospatial.org/standards/citygml (accessed on Jan. 10 2010).

[6]http://www.agi.com/products/stk/(2014/07/18).

[7]Chia-Ming Liu, ”Feature Extraction from LIDAR PointCloud Data”, Master Thesis, National Cheng Kung University, Tainan, Taiwan, ROC, 2005. (in Chinese)

[8]Clément Mallet, and Frédéric Bretar, “Full-waveform topographic lidar: State－of－the-art”， ISPRS Journal of Photogrammetry and Remote Sensing 64, pp.1-16, 2009。

[9]Ming-Da Tsai and Chia-Chyang Chang, “Impact of Digital Battlefield on Future Wars”, Army Bimonthly, No. 470, pp. 78-79, 2004. (in Chinese)