HIGH RESOLUTION DEM PRODUCTION USING MODIFIED INTERPOLATION METHODS (QUADRANT & OCTANT)

Nabeel J. Tawfiq , Faleh H. Mahmood &Israa J. Muhsin
Remote Sensing unit, College of science, University Of Baghdad. Baghdad-Iraq.

Abstract

A digital elevation model (DEM) is a digital file of terrain elevations for ground positions. It is a raster representation of the elevation of the ground and objects, such as buildings and trees, with pixel values in the images, as well as the wide range of uses and applications. In this research, the Easting, Northing, and Elevation, data set had been gathered, they collected by performing field survey using global Positioning system (GPS). Modified an interpolation method had been presented it depends on Quadrant and Octant methods to produce a DEM surface. Some classic techniques such as Nearest neighbor and universal Kriging, have been used for comparison purpose with the results of the new technique. A new technique has been used it depends on multilayer processing, mosaic model have been applied between the layers to perform the high resolution DEM. A 3-D image has been produced as one of the most important application of DEM.

إنتاج نموذج الارتفاع الرقمي بدقة عالية باستخدام طرق استكمالية مطورة (رباعية – ثمانية)

نبيل جميل توفيق، فالح حسن محمود، إسراء جميل محسن
وحدة الاستشعار عن بعد، كلية العلوم، جامعة بغداد

الخلاصة

نموذج الارتفاع الرقمي هو ملف رقمي يمثل ارتفاع تضاريس لمواقع محددة على الأرض وهو عبارة عن تمثيل نقطي لارتفاعات الأهداف الأرضية مثل البنايات والأشجار، كتمثيل صوري، بالإضافة الى انه يمتلك مدى واسع من الاستخدامات والتطبيقات.

في هذا البحث تم جمع احداثيات (الشرق – الشمال – الارتفاع) بواسطة المسح الحقلي باستخدام نظام التموضع العالمي (GPS). استخدمت في البحث طرق استكمال مطورة تعتمد على آلية البحث الرباعي والثماني لبناء سطح نموذج الارتفاع الرقمي. استخدمت طرق تقليدية مثل طريقة الجوار الأقرب وطريقة كركنج الشامل (universal Kriging) للمقارنة مع الطرق الجديدة. استخدمت تقنية جديدة تعتمد على معالجة متعدد الطبقات، نموذج الموزاييك طبق بين الطبقات لإنتاج الشكل النهائي لنموذج الارتفاع الرقمي، نموذج مجسم ثلاثي الإبعاد تم بناءه ويعد تطبيق مهم لنموذج الارتفاع الرقمي.

Introduction

The term Digital Elevation Model (DEM) has several meanings, it is not always understood correctly, it is misinterpreted due to the surface it represents or geographic location the DEM data is being used. As used in most of the western hemisphere a DEM has "Bare Earth" z-values at regularly spaced intervals in x (Easting's) and y (Northing's). In some countries the x and y orientation are opposite from the general use with "x" being Northing and "y" Easting.

Because of many different horizontal and vertical geodetic reference systems available around the world the necessity to clearly define the 3D geodetic reference system to be utilized is critical to a projects success to obtain the mapping standards defined. There is a variety of DEM source data available for developed areas. The suitability of this available data depends on the project specifications. In remote regions around the World, were little or no source Data is available, the DEM can be produced by automatic DEM extraction from stereo satellite scenes, from Satellite sensors such as QuickBird (0.6m), IKONOS (2-5m resolution) , SPOT-5 (5-10m res.) and ASTER (15-25m res.). The DEM can also be provided from Stereo Digital Aerial Photography at various resolutions, depending on the quality and scale of the Aerial Photography [1].

A DEM is used as a mean of 3-D terrain modeling; it serves as a basic source of information for deriving geo-spatial uniqueness. Currently, Digital elevation modeling (DEM) is one of the modern methods for representing the topographic surface of the terrain, (i.e., how the elevation of the ground surface is changing with position). Traditionally this has been done by contour lines on topographic maps. DEMs being generated by many methods, such as ground survey, photogrammetry, Light Detection and Ranging (LIDAR), and Global positioning system (GPS) techniques which have been adopted to generate high resolution digital elevation model [2].

Study Area and Available Data

The study area, in this research, is located in the middle of Baghdad City, it is the area represent covered by Baghdad university complex. It is consist of different buildings (belong to various colleges and its department), vegetation and some of trees which cover the land between buildings. The geographic coordinates are : (1) Latitude (33º 16' 55.6") to (33º 16' 4.5") N, (2) Longitude (44º 22' 11.8") to (44º 23' 20.4") E. The satellite scene is belong to QuickBird satellite, the projection is Universal Transverse Mercator (UTM) zone(38) and the datum is World Geodetic System (WGS 84), (see figure 1).

Figure 1: The image of studied area (Baghdad University)

Global Positioning System (GPS)

Microwave signals transmitted by Global Positioning System (GPS) satellites are increasingly used for high-accuracy scientific applications including studies of weather, climate, crystal deformation, plate tectonics, sea level, and ice dynamics. The 24 GPS satellites broadcast 1.575 (L1) and 1.228 (L2) GHz carriers based on atomic clocks. Receivers for high accuracy tracking of these two carriers are commercially available at relatively low cost. The Global Positioning System (GPS) is a satellite based navigation system and is designed to operate 24 hours in all weather for Global coverage. The system has three segments. A space segment including 24 GPS satellites in 6 orbital planes. They transmit the data of ephemerid, almanac line, satellite health, ranging signal and atmospheric conditions. A control segment includes the ground monitor command and control function. It performs the tracking, orbital determination, time synchronization function. A user segment includes GPS receiver, which tracks the satellites and identifies the individual satellites. The receiver decodes the satellite signals and computes the position such as latitude, longitude and altitude [2,3].

Nearest Neighbor Gridding

The Nearest Neighbor gridding method assigns the value of the nearest datum point to each grid node. This method is useful when data is already on a grid, but needs to be converted to a Surfer grid file. Or, in cases where the data is nearly on a grid with only a few missing values, this method is effective for filling in the holes in the data.

Sometimes with nearly complete grids of data there are areas of missing data that you want to exclude from the grid file when you want to use the Nearest Neighbor method to convert regularly spaced XYZ data to a grid file, you can set the grid spacing equal to the spacing between data points in the file [4].

The planimetric distance(di)between the reference point and the ith interpolation points can be given as:

$$d_i = \sqrt{(X_i - X)^2 + (Y_i - Y)^2} \quad \text{.......(1)}$$

Universal Kriging

One of the assumptions made in kriging is that the data being estimated is stationary. That is, as you move from one region to the next in the scatter point set, the average value of the scatter points is relatively constant. Whenever there is a significant spatial trend in the data values such as a sloping surface or a localized flat region, this assumption is violated. In such cases, the stationary condition can be temporarily imposed on the data by using of a drift term [5]. The drift is a simple polynomial function that models the average value of the scattered points. The residual is the difference between the drift and the actual values of the scattered points. Since the residuals should be stationary, kriging is performed on the residuals and the interpolated residuals are added to the drift to compute the estimated values. Using a drift this function is often called "universal kriging." the mathematical model of universal kriging is as follow [1]:

$$\begin{bmatrix} \gamma\{d_{11}\} & \gamma\{d_{12}\} & \gamma\{d_{13}\} & \gamma\{d_{14}\} & \gamma\{d_{15}\} & 1 & X_1 & Y_1 \\ \gamma\{d_{21}\} & \gamma\{d_{22}\} & \gamma\{d_{23}\} & \gamma\{d_{24}\} & \gamma\{d_{25}\} & 1 & X_2 & Y_2 \\ \gamma\{d_{32}\} & \gamma\{d_{32}\} & \gamma\{d_{33}\} & \gamma\{d_{34}\} & \gamma\{d_{35}\} & 1 & X_3 & Y_3 \\ \gamma\{d_{41}\} & \gamma\{d_{42}\} & \gamma\{d_{43}\} & \gamma\{d_{44}\} & \gamma\{d_{45}\} & 1 & X_4 & Y_4 \\ \gamma\{d_{51}\} & \gamma\{d_{52}\} & \gamma\{d_{53}\} & \gamma\{d_{54}\} & \gamma\{d_{55}\} & 1 & X_5 & Y_5 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ X_1 & X_2 & X_3 & X_4 & X_5 & 0 & 0 & 0 \\ Y_1 & Y_2 & Y_3 & Y_4 & Y_5 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ \lambda \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \gamma\{d_{1p}\} \\ \gamma\{d_{2p}\} \\ \gamma\{d_{3p}\} \\ \gamma\{d_{4p}\} \\ \gamma\{d_{5p}\} \\ 1 \\ X_P \\ Y_P \end{bmatrix} \text{..............(2)}$$

Where:-

λ : is Lagrange multipliers.

a1 and a2: the coefficients expressing the trend (two coefficients).

Quadrant and Octant methods

The search for nearest neighbors may involve a simple area search with a circle of predefined radius or a box of predefined size used to select the data points from which the grid point value is determined. The problems with simple of this search according to Euclidean distance is all the nearest points may lie in a narrow wedge on one side of the grid node and the resulting estimate of the node is essentially unconstrained, except in one direction. The solution of this problem is restrict the search in some way which ensures that the reference points are equally distributed around the grid node being estimated [4],(See figure 2).

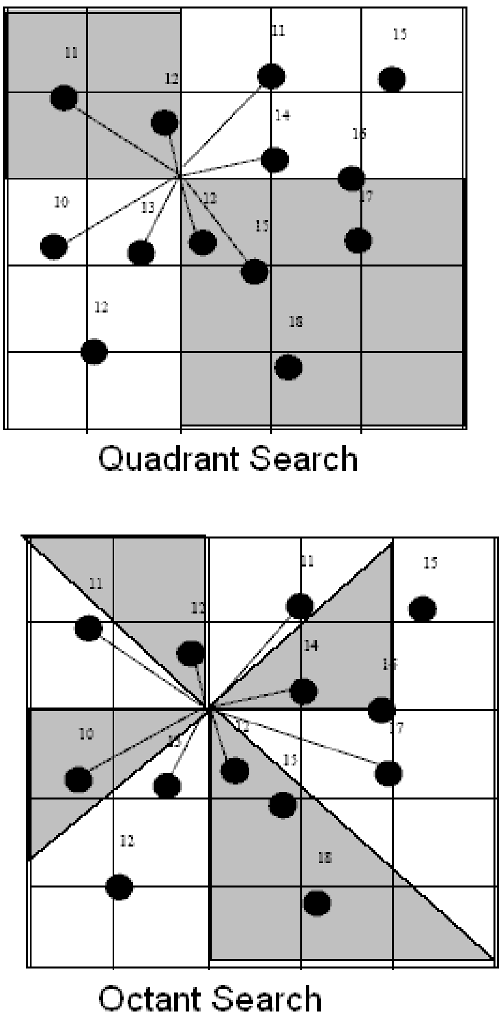


Figure 2: The search algorithm by quadrant and octal.

Mosaics

Photomaps may be prepared from single aerial photos, or they may be made by piecing together two or more individual overlapping photos to form a single continuous composite picture. These composites are commonly referred to as mosaics. Photomaps or mosaics are similar to maps in many respects, but they have a number of advantages over maps, they show relative planimetric locations of an infinite number of objects, whereas features on map which are shown with lines and symbols must be limited in number, photomaps or mosaics of large areas can be prepared in much less time and at considerably lower cost maps and they are easily understood in and interpreted by people without photogrammetry or engineering backgrounds because objects are shown by their images. Therefore, the useful in describing proposed construction or existing conditions to members of the general public, who would probably be confused by the same representations on map[6]. In this research the mosaic model have been applied between the base layer and buildings layer.

Methodology

To built the surface of DEM two adaptive girding methods have been used (quadrant and octant search), These methods were applied to produce DEM, indirectly, to all points whose coordinates are gathered (GPS). The data consist of base and building of studied area of Baghdad university don't give it acceptable result and there is large error in calculating the height of building because the overlap between the values of the base and the building To overcome this problem (overlap between base and building of studied area), this search introduced a new technique, it used to build a high resolution digital elevation model for any region consist of many buildings. This technique implies the following steps:

Step one: compute the elevation of each point by GPS, The results are shown in figure (3).

Step two: separate the building data from the base data to represent each one as a layer.

Step three: specify the building layer as polygons and reclassified them to give each polygon height measured by GPS the result of specification is shown in figure (4).
Step four: apply Quadrant an Octant search on the base layer. The result is shown in figure (4).
Step four: apply static search such as nearest neighbor gridding show in figure (5).
Step five: mosaic model have been used to obtain the final digital elevation model with high resolution, the result of mosaic model is shown in figure (6).
Step six: geometric correction and rectification using first order polynomial had been used to correct the image of studied area.
Step seven: combine the corrected satellite image for the studied area with final DEM of the same area to produce 3-D photo image The result can be shown in (figures (7&8))

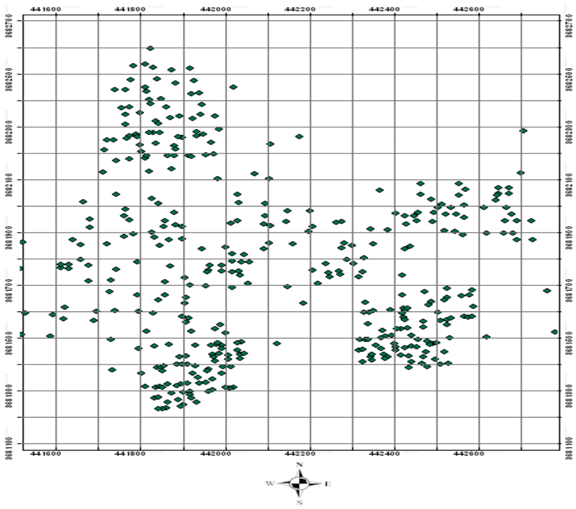


Figure 3: The points distribution

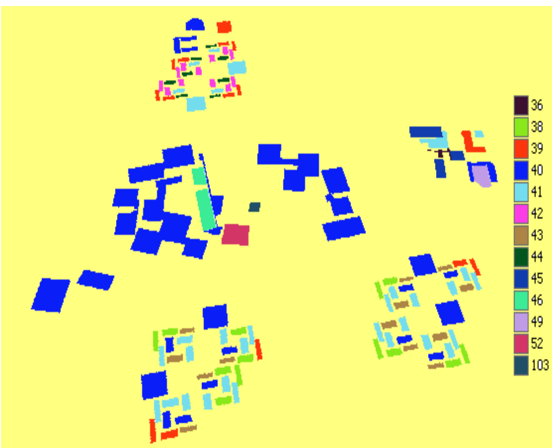
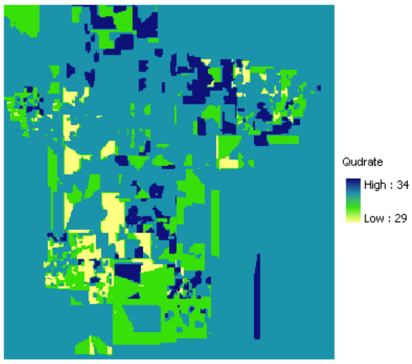
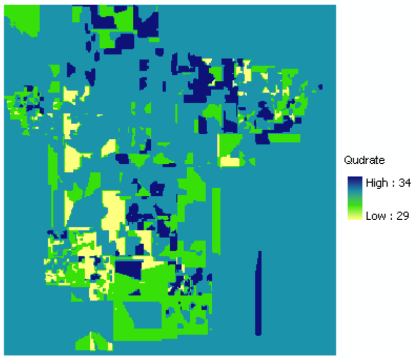


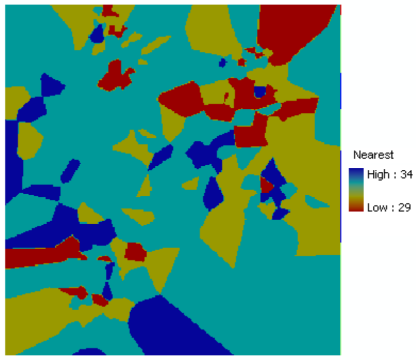
Figure 4: Reclassify of buildings.



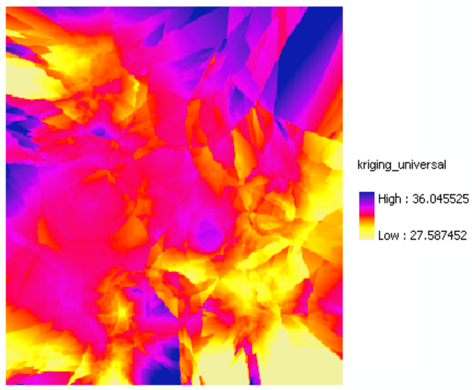
DEM of base by Quadrant method



DEM of base by Octant method

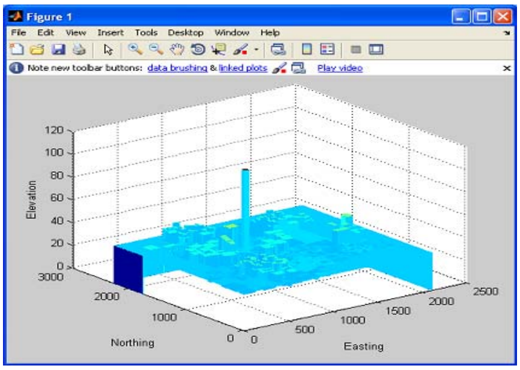


DEM of base by Nearest neighbor

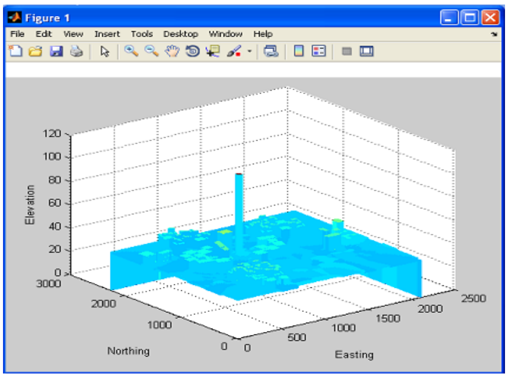


DEM of base by Universal Kriging

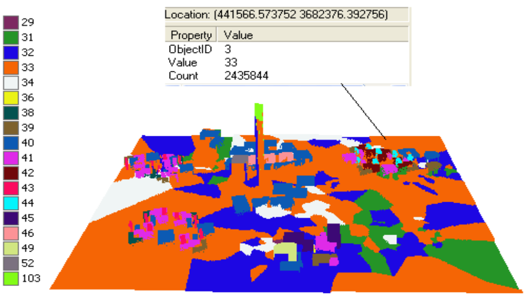
Figure 5: DEM of base layer by different techniques



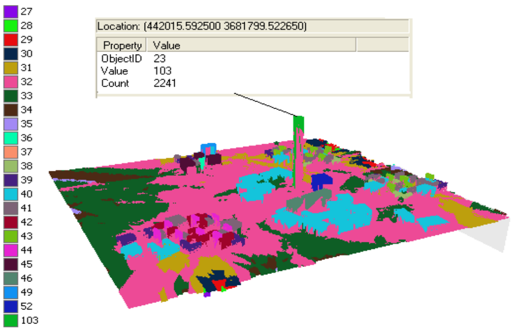
Mosaic model (Quadrant)



Mosaic model (Octant)



Mosaic model (nearest)



Mosaic model (kriging)

Figure 6: Mosaic Model Results.

Geometric Correction (Rectification)

In general remotely sensed image data are gathered by a satellite or aircraft represent the irregular surface of the Earth. Even images of seemingly flat areas are distorted by both the curvature of the Earth and the sensor being used. [7].

GCPs are specific pixels in an image for which the output map coordinates (or other output coordinates) are known. GCPs consist of two X, Y pairs of coordinates:

•***Source coordinates:*** usually image coordinates in pixel unit.

• ***Reference coordinates:*** the coordinates of the map or reference image to which the source image is being registered. In this search the GCPs specified on the original image and it had been computed by GPS navigator. The (GCPs) coordinates are shown in table (1).

Table 1: The GCPs points

ID	Easting	Northing
1	442302.30	3681780.75
2	441956.88	3681751.77
3	441945.61	3681838.38
4	441974.49	3681534.80
5	441800.48	3681367.29
6	441526.78	3681594.31

Data Accuracy

To evaluate the accuracy of the mathematical techniques used for producing the DEM, twenty random points were chosen on each transferred models and its coordinates were recorded (E, N, Elev.). The elevations of these points are computed using the adapted methods. Then these determined elevations of all used methods are compared with the elevation compute by DGPS which represent the more accurate elevation.

The results of the accuracy can be shown in table (2), and the Comparison have been done by calculating the Root Mean Square Error (RMSE) which can be defined as[8]:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Z_i - Z_d)^2}{N}} \quad \ldots\ldots (3)$$

Where:

Z_i = Interpolated DEM elevation of a test points.

Z_d = Real elevation of a test points.

N = Number of selected points

Table 2: Data Accuracy.

No.	Methods		nearest	kriging	quadrant	octant	DGPS
	Coordinates		(Z1)	(Z2)	(Z3)	(Z4)	Z(real)
	Easting (X)	Northing (Y)					
	442700.66	3682124.62	32.4	31.47	32.42	32.43	31.5
	442148.33	3681694	32.49	31.29	33.42	31.49	31.75
	442057.97	3681787.73	31.63	32.15	33.43	33.14	32.79
	441927.91	3681396.56	31.63	31.71	32.2	31.44	32.65
	441812.28	3681526.51	32.45	31.38	31.35	31.87	33.32
	441734.05	3681380.18	31.54	31.5	32.9	32.6	32.78
	442467.65	3681564.55	31.358	31.4	32.22	31.89	34
	442331.68	3681635.74	31.362	31.64	30.89	31.89	31
	442174.43	3682263.63	31.15	31.44	32.73	32.82	32.2
	441517.46	3681766	32.48	32.26	32.47	31.47	33.5
	441523.79	3681857.77	33.38	32.39	32.34	32.32	33.5
	442009.18	3681937.1	32.54	31.59	32.38	32.52	32.5
	442090.45	3681933.23	33.16	31.46	32.72	33.08	32.5
	442410.91	3681730.43	31.63	31.41	32.46	32.38	32.66
	442089.68	3681837.25	32.16	31.4	32.96	32.35	33.67
	442704.27	3682280	32.5	31.19	32.17	31.3	31.5
	442023.89	3682103.52	32.45	31.35	32.26	31.23	32.72
	442324.94	3681750.56	32.43	32.56	31.21	31.85	33.5
	442454.25	3681977.35	30.52	30.4	32.26	32.48	32.2
	442366.16	3682059.88	31.3	31.1	32	31.2	31.77
	RMSE		0.5725	1.046	0.2610	0.513	

Production of a 3-D Image

After the correcting of satellite image, and producing the DEM for the specific area, the georeference satellite image of study area could be merged with raster digital elevation model for producing photo image.This part of work has been performed by combining the corrected satellite image for the studied area with raster DEM of the same area. The result is presented in figures (7 and 8):

Figure 7 : The 3-D photo image merge with final DEM using universal kriging technique

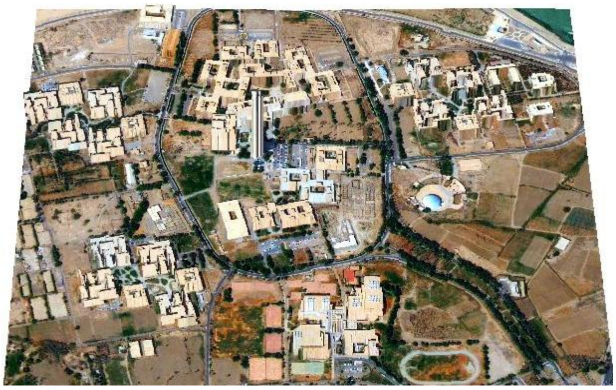


Figure 8 : The 3-D photo image merge with final DEM by nearest neighbor technique.

Figure 9: The 3-D photo image merge with final DEM by quadrant technique.

Figure 10 The 3-D photo image merge with final DEM by octant technique.

Discussion and Conclusion

Most of the researches whose care for DEM productions fields dealing with rough terrain. This research study was an attempt to generate DEM of region consist of geometric buildings, so there are two types of elevation points one for the base of studied area and the other for the buildings and apply the interpolation methods indirect on all the points of base and buildings make large error because the overlap between the base and buildings points, this research present modern technique to solve the overlapping problem, this technique depend on multilayer processing, where the interpolation methods have been applied on the base layer and specify the buildings as polygons as another layer, then apply the mosaic model between the two layers to achieve the final DEM. Two static interpolation methods have been applied on base layer and two adapted interpolation methods suggested in this research called (octant and quadrant), from the results of root mean square error between the elevation which computed by the using all the methods and the real elevation computed by differential global poisoning system (DGPS) it note that the adapted methods give (RMSE) less than the static interpolation methods. This research present successful technique for producing DEM of buildings region as well as this research give a new and adaptive interpolation techniques

References

1. Cooper, P.R. **1987**. The Automatic Generation of DTMs from Satellite Imagery by stereo. *Acta Astronomical Journal*, **15**(3): 171-180.
2. Al-Nadawee, G. S. **2009**. Accuracy Assessment of Digital Mapping Using Differential GPS. M.Sc. Thesis. Department of Surveying Engineering. College of

Engineering. University of Baghdad. Baghdad, Iraq. Pp. 21-24.

3. "GPS guide for bigginers", USA**,(2000)**. www.Garmin.com,
4. Habib, A. **2003.** Digital Terrain Model. http://www.geomatics.ucalgary.ca/~habib/courses/engo573/akam-ch-3-1.pdf
5. ESRI, **2001**. *What is Arc GIS*. Computer Program.
6. Al-Aubaidi, N. K. **2007.** Aerial Mosaicing and DEM production using Bundle Block Adjustment Techniques. Ph.D. Thesis. Department of Physics, College of Science, University of Baghdad, Baghdad. Iraq. pp.70-71.
7. Schowengerdt, A. R, **2007**. *Remote Sensing Models and Methods For Image Processing*. Third Edition. Elsevier Inc. http://www.ucalgay.ca/uofc/faculties/ss/GeoG/virtual/remoteintro.html.
8. Gonzalez, R. C. and Woods, R. E. **2002**. *Digital Image Processing***.** Second Edition**,** Prentice Hall, Inc., p.p. 419.