Accuracy Assessment of Srtm-Dem Using Gps Measurments and Gis Techniques

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Abstract

Shuttle Radar Topographic Mission (SRTM) has created datasets of global elevations that is freely available for modeling and environmental applications. The global availability (almost 80% of the Earth surface) of SRTM data provides baseline information for geospatial applications such as mapping, hydrology, navigation, GIS applications, and reconnaissance. Assessment of the accuracy of SRTM requires regional studies involving points with known elevations at higher level of precision than the SRTM, usually measured with Global Positioning System (GPS).

This study based on datasets collected with a differential GPS system in different locations in Iraq. These measurements were corrected with differential methods to reach to sub – centimeter accuracy. Statistical analysis included estimation of absolute errors by Root Mean Square Error (RMSE), Standard Deviation (SD). RMSE was found as (5.15m) for Iraq and the SD was (3.93). This is higher than the standard SRTM-DEM accuracy which is (16m)

Keywords: SRTM, spatial join, GPS, accuracy assessment, DEM.

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تقييم دقة نموذج الارتفاعات الرقمية بأستخدام قياسات منظومة الاحداثيات العالمية و تقنيات نظم المعلومات الجغرافية

الملخص

مهمة المسح الطوبوغرافي للمكوك الراداري (SRTM) هي الحصول علـــى نمـــاذج الارتفاعات الرقمية حول الكرة الارضية لتوفيرها مجانا لأغراض النمذجة الثلاثيـــة الابعـــاد و التطبيقات البيئية. حجم البيانات المتوفرة يغطي (80%) من سطح الارض. هذه البيانات تـــوفر خط القاعدة من المعلومات التي يمكن استخدامها في التطبيقات المكانية مثـــل رســـم الخـــرائط, الهايدرولوجي, الملاحة, تطبيقات نظم المعلومات الجغرافية, و المسوحات الاستطلاعية.

الهدف من هذه الدراسة هو لفحص دقة بيانات نموذج الارتفاعات الارضية العالمي - SRTM) DEM) في العراق من خلال المقارنة مع نقاط معلومة المنسوب ذات دقة عالية تم الحصـــول عليها بواسطة قياسات منظومة المواقع العالمية (GPS)

هذه الدراسة مستندة الى نقاط تم قياسها بأستخدام جهاز قياس المواقع العالمي من النوع التفاضلي (DGPS) في اماكن مختلفة من العراق. تم تصحيح هذه القياسات بأستخدام الطرق التفاضـــلية للوصول الى دقة تصل الى اجزاء السنتمتر للنقطة الواحدة. التحليلات الاحصائية تضمنت تخمين نسبة الخطأ المطلق عن طريق جذر متوسط مربع الخطأ (RMSE) و الانحـــراف المعيـــاري (SD). وجد ان جذر متوسط مربع الخطأ يساوي (5.15m) و الانحراف المعيـــاري يســـاوي (3.93m) و هي اعلى من الدقة القياسية ل (SRTM) و البالغة (16m) .

Introduction

A lack of suitable topographic data has long been an obstacle to the study of the environment, especially for most developing countries (including Iraq). New remote sensing technologies had now begun to change this situation. DEMs can be generated by laser scanning, photogrammetric methods or Interferometric Synthetic Aperture Radar (InSAR). In any case, it is time consuming and expensive. The worldwide lack of qualified and accessible DEMs has been improved with the Shuttle Radar Topographic Mission (SRTM) in February 2000.

SRTM used the InSAR technique for the determination of a nearly worldwide height model. The space shuttle carried two radar antenna combination – one of these located in the shuttle's cargo bay, and the other at the tip of a 60m long mast (Figure 1), both for C-Band and X-Band [1].

The SRTM data products result from a collaborative mission by the National Aeronautics and Space Administration (NASA), the National Imagery and Mapping Agency (NIMA), the German Space Agency (DLR) and Italian Space Agency (ASI), to generate a near-global digital elevation models (DEMs) of the earth using radar interferometry [2].

The SRTM is a large scale survey that collected interferometric radar topography data between latitudes (56^o S) and (60^o N). As the first set of continuous data covering most of the Earth's surface, it overcomes the deficiencies of conventional maps that have a variety of scales and levels of precision around the world [3].

The SRTM data can be freely downloaded form NASA's Jet Propulsion Laboratory website. There are two resolutions of SRTM data at this website, one is 1 arc second (30m) for US (SRTM1), and another one is 3 arc seconds (90m) for the rest of the world (SRTM3). But there are voids about (0.25%) of the total area in these data. ESRI Inc. has supplied void – filled SRTM data since 2006 when releasing the new version of ArcGIS9.2. It was therefore more convenient for use.

Geospatial applications such as mapping, hydrology, navigation, GIS, mission planning and simulation require the construction of a high resolution DEM of land surfaces of the earth. SRTM provides an excellent representation of the real world with the resolution of 90m. The absolute accuracy of the SRTM were stated as ±16m vertical linear error [2].

Several researchers have been proposed a thorough evaluation of the SRTM vertical accuracy. For instance, Gorokhovich and Voutianiouk, [4], in their study to assess the accuracy of the SRTM – based elevation data noted that an overall assessment of the accuracy of the product requires additional regional studies involving ground truth control and accuracy verification methods with higher level of precision.

The vertical accuracy of the SRTM has been extensively investigated in many studies. Y. Liu, [5], had evaluated the data quality of the SRTM – DEM at the Alpine and Plateau area, north western of China and determined the relationship between SRTM vertical error and certain topographic characteristics derived from SRTM such as slope and aspect.

A. K. Karwel and I. Ewiak, [6], estimated the accuracy of SRTM terrain model on the area of Poland. This study has been performed on the basis of reference terrain profiles measured by GPS. They presented the accuracy of the SRTM model by Root Mean Square Error (RMSE) which was computed on the basic of height difference between profiles and model homolog points. The absolute accuracy of SRTM model on Polish area was found to be (2.9m) for flat regions and (5.4m) for hilly regions

STUDY AREA

The study area (Iraq) lies between latitudes (29^o.06 N) and (37^o.38 N) and longitudes (38^o.79 E) and (48^o.56 E). Figure (2) shows the SRTM – DEM of Iraq presented as Color–coded image. The area of Iraq is approximately (436420 km^2) represented different surface forms situated in (18) administration boundary land. The elevations range from 0 (in some places in Basra) to more than (3000 m) in the north.

Experimental work and measurements

The accuracy test conducted in this study employed two sources of spatial data. (90m) resolution SRTM – DEM data, and GPS point data. The SRTM - DEM used in this study was that distributed by ESRI in ArcGIS 9.2 software.

GPS point data used in this study were acquired using Trimble 5700 Differential GPS receivers with horizontal and vertical accuracy of (±1cm) in kinematics survey mode and (±0.5cm) in static survey mode (Trimble 5700 data sheet). About (694) points have been measured in different parts of Iraq using the GPS. The researcher had measured these points while working on some survey projects. These projects included (Iraqi marshes refreshing project, Musaib – Semawa Railway project, Kirkuk base map project, Karbala developing project.

Figure (3), shows the distribution of the GPS points.

The GPS points covered an area of about (210000km2) which is approximately (48%) of the total area of Iraq.

In order to evaluate the accuracy of the SRTM data, a comparison between the SRTM – DEM and the GPS measurements was performed. GPS point data are considered as Ground Control Points (GCP). This comparison basically involves computing the Root Mean Square Error (RMSE) eq. (2) and the Standard Deviation (STD) eq. (3) statistic of the elevation differences between the SRTM data and a reference dataset, such as GPS measurements.

The comparison is performed as follows:

$$d = Elv_{GPS} - Elv_{SRTM} \qquad (1)$$

Where:

d : is the difference in height

Elv_{GPS} : is the elevation of the Ground Control Point as measured by GPS

Elv_{SRTM} : is the elevation of the same point obtained from the SRTM - DEM

The differences in height (d) were computed for all GPS points (694 points). The Root Mean Square Error (RMSE) between SRTM - DEM and the GPS elevations can be used to measure SRTM–DEM accuracy:

$$RMSE = \sqrt{\frac{\sum d^2}{N}} \qquad (2)$$

and in order to show the variability of measurements from the mean, the standard deviation that implies index of precision of the model:

$$STD = \sqrt{\frac{\sum (d - \bar{d})^2}{N-1}} \qquad (3)$$

can be calculated, where the mean:

$$\bar{d} = \frac{\sum d}{N}$$

is a residual mean that describes the difference between the SRTM– DEM surfaces and the GPS measured points.

Data analysis

The analysis requires overlaying the GPS points on the SRTM - DEM and extracting the heights from two datasets. But these data were of two different types: raster (SRTM – DEM) and point data (point feature class). In order to overlay these data, they must be converted into one compatible form. In this study, the SRTM – DEM data were converted into a polygon feature class with an attribute table storing the elevation value. Thus, each polygon replicated raster pixel and was overlaid with the GPS point dataset. This operation is also known as Spatial Join in ArcGIS software. Spatial join creates a table join in which fields from one layer's attribute table are appended to another layer's attribute table based on the relative locations of the features in the two layers [7].

In this project, the spatial join was between polygons (the SRTM - DEM vector) and points (GPS measurements). Each resulting point will be given all the attributes of the polygon that it falls inside. Join by location or spatial join uses spatial associations between the layers involved to append fields from one layer to another. The result of this operation was saved to a new output layer [6].

Gorokhovich and Voustianiouk in 2006, described this method for performing the overlay. Their approach involved first converting the SRTM raster dataset into a vector – based GIS layer containing as many polygons as there were grid cells (pixels) in the SRTM - DEM data and then performing a spatial join of the point data and the new polygon layer to extract the height data for the statistical analysis.

The result is a point layer; its attribute table contains height information from two sources; one from the GPS points and the other from the SRTM – DEM polygons. This attribute table was then exported as dBase table which was open in Microsoft Excel to perform the statistical analysis.

Accuracy assessment

Assessment of the accuracy of SRTM model was presented as by root mean square error, and standard deviation

between the SRTM - DEM values and the check point of GPS values. RMSE and STD were computed to each governorate separately and to the total area of Iraq. Table (1) shows the results of each governorate. The overall accuracy of the SRTM– DEM for Iraq. RMSE was equal to (5.15m) and the STD was (3.93). This is higher than the standard accuracy of the SRTM - DEM which was (16) as published in the SRTM data specifications.

Results

- The statistical computation for the absolute vertical accuracy of SRTM – DEM for the study area gave a value of (5.15m). This indicates that (90m) SRTM – DEM, for the study area, featured (3) or (4) times higher than the absolute vertical accuracy of the SRTM published in the SRTM data specifications.
- The results of accuracy assessment also depend on the number of GPS readings per one spatial unit of SRTM (pixel). The

more GPS readings would be available, the more accurate the final estimation will be. However, implementation of this approach requires special planning of GPS surveys and considerable additional resources, and was not within the scope of the present study.

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Table (1): The accuracy assessment Results

Governorate	No of GPS points	RMSE	STD
Karbala	4	2.26	2.06
Qadissiya	64	3.23	3.11
Muthanna	89	5.30	4.81
Basrah	84	3.25	3.22
Najaf	62	3.62	3.46
Thi-Qar	44	3.25	2.79
Babil	24	4.57	4.29
Wassit	15	3.33	2.85
Missan	45	2.81	2.55
Salah al-Din	72	5.70	4.60
Anbar	117	7.77	5.86
Diyala	50	4.65	3.46
Baghdad	6	11.11	8.98
Taamim	18	15.67	7.99

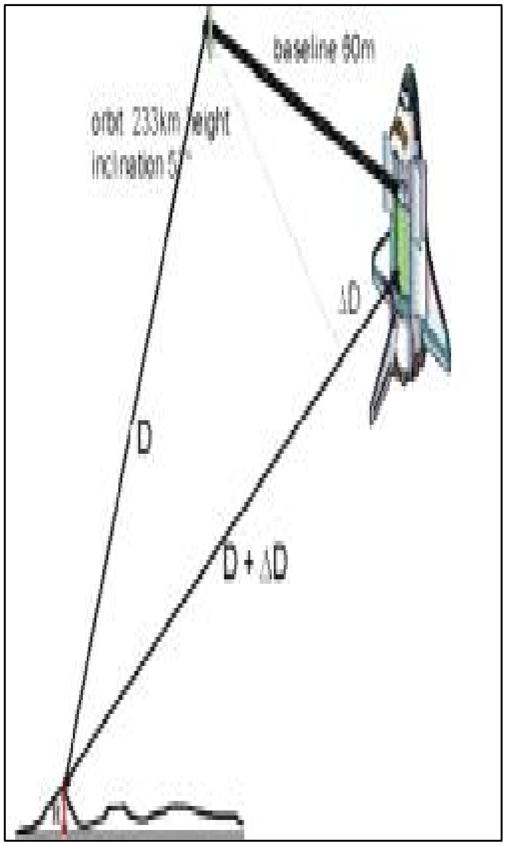

Figure 1: Principles of SRTM

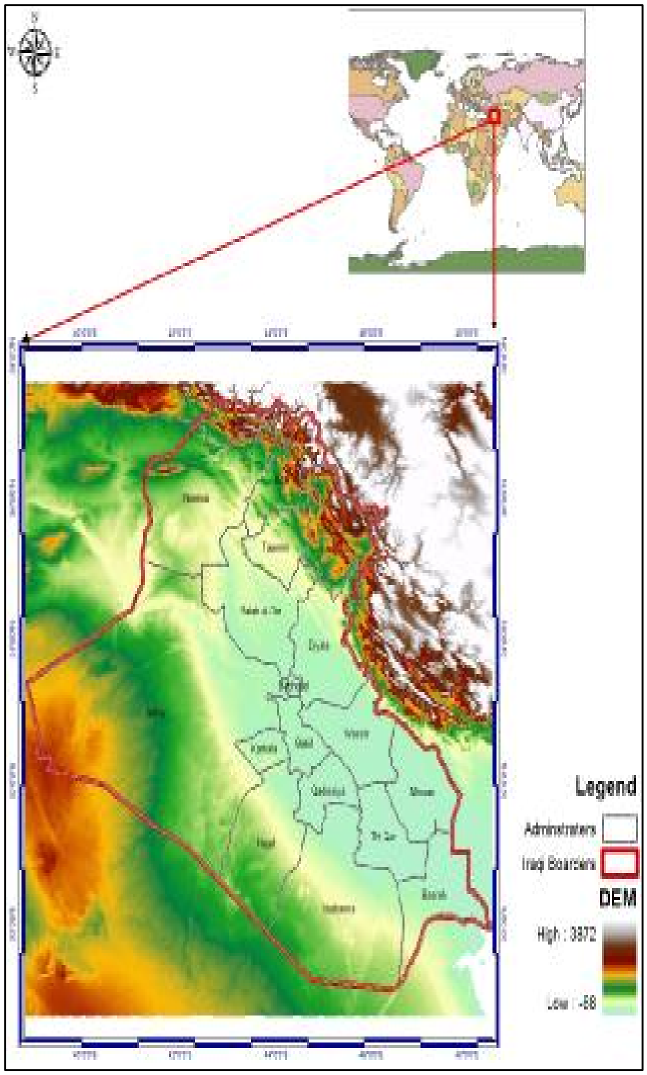

Figure 2: Map of the Study area

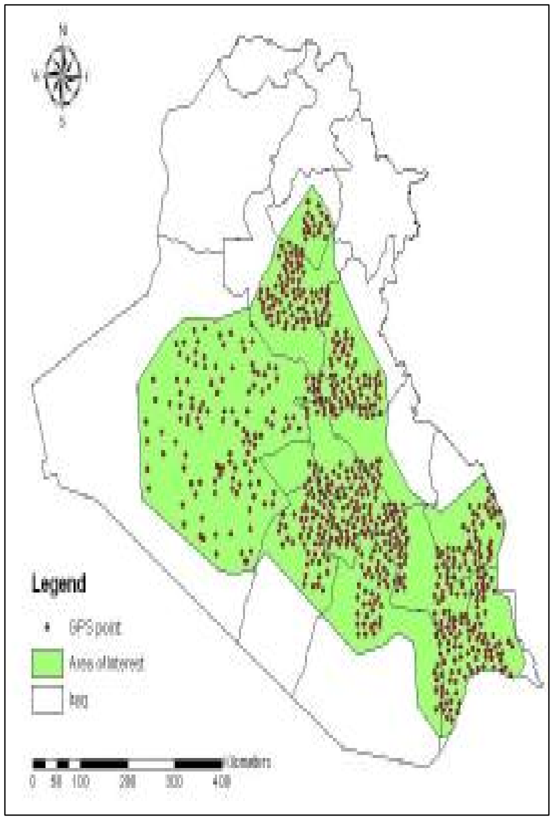

Figure 3: Distribution of the GPS points