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Accuracy of satellite image rectification using PPP-GPS versus DGPS

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Abstract: In this study, satellite image obtained from Spot-5 (2.5 m) sensor was rectified by means of PPP-GPS (Precise Point Positioning using Global Positioning System) and DGPS (Differential Global Positioning System). Rectification of Spot image was carried out using 8 GCPs (Ground Control Points) covering an area of 9.15 km^2. The coordinates for GCPs were obtained using two techniques; PPP and DGPS. The accuracy of the image rectification using both techniques was evaluated using 3 GCPs as check points. A satellite image obtained from Geoeye (0.50 m) sensor covering the same area was rectified by using (PPP-GPS) 8 GCPs and its accuracy assessed using 3 check points.

Keywords: Rectification, PPP, Differential, GPS

1. Introduction

The production of topographic maps for enormous land areas is possible with less cost and time by using remote sensing satellite images. Satellite images are preferable because of revisit, economic, synoptic and rapid data acquisition (Saroglu et al., 2005). Satellite images have geometric distortion due to the curvature of the earth, the rotation of the earth during image acquisition, sensor non idealities and variations in platform altitude, attitude and velocity. Rectification of satellite images is a significant procedure to eliminate geometric distortions of the image and provides integration of remotely sensed data with spatial databases and geographic information systems (GIS). Rectification is the process of transformation of pixel coordinate system into ground coordinate system by using a geometric model such as polynomial equations (Jensen, 1996; El-Manadili and Novak, 1996; Saroglu, 2004).

Several articles have been published about the various techniques used for geometric correction of satellite imagery. GPS derived and topographic map derived data are alternative sources for rectification process. (Smith and Atkinson, 2001; Cook and Pinder, 1996; August et al., 1994; Karduolas et al., 1996).

This research study contains two parts; first, the rectification of satellite Spot-5 image (Spot, 2013 - 2.5 m resolution) using 8 GCPs whose coordinates were acquired from two techniques; PPP –GPS and DGPS. The accuracy of each technique was examined by computing the RMSE (Root Mean Square Error) of 3 GCPs as check points. Secondly, the rectification of satellite Geoeye image (Geoeye, 2013 - 0.5 m resolution) using 8 GCPs whose coordinates were acquired from PPP –GPS. Also, the accuracy of this technique was examined by computing the RMSE of 3 GCPs as check points.

2. Study area and satellite data

The study area is in the northwestern part of Riyadh city, the capital of kingdom of Saudi Arabia. It is the campus of KSU (King Saud University). It extends from 24° 42′ E to 24° 44′ E in longitude and from 46° 36′ N to 46° 38′ N in latitude, covering an area of 9.15 km^2. The satellite images used for the study were provided by King Abdulaziz City for Science and Technology (KACST) (KACST, 2013). The Spot-5 image (Spot, 2013) acquired on 10 January 2012 is shown in Figure 1. The Geoeye image (Geoeye, 2013) acquired on 12 January 2012 is shown in Figure 2.

Ground control points (GCPs) and check points (CPs) which can be clearly identified on the satellite sensor images were selected and field survey was performed for establishing coordinates of GCPs and CPs. Coordinates of 11 GCPs were obtained by using PPP-GPS and DGPS techniques. Eight GCPs were used for the rectification process and 3 GCPs were used as check points. Figure 3 shows the distribution of the GCPs on the study area.

3. Methodology

3.1 Rectification

Remote sensing technology has been used for many years for different applications. Remote sensing images usually go through correction process before the information extraction process. Remote sensing data contain geometric distortions due to the earth curvature, relief displacement and the acquisition geometry of the satellites (i.e. variations in altitude, aspect, velocity, panoramic distortion). The aim of rectification is to minimize the geometric distortions introduced by these factors and register image data to a map projection (Lillesand and Kiefer, 2000). Rectification is the process of projecting the image data onto a plane surface and making it align to a map projection system such as Universal Transversal Mercator (UTM).

Rectification of satellite images involves, among other things, the establishment of ground control points that link each image to its corresponding coverage on a digital orthophoto quarter quad (DOQQ) that serves as the base map. Points are chosen on the image that can be matched to points on the DOQQ. Road intersections and other cultural features are preferred as reference points rather than natural features.

The experimental work is conducted using Earth Resources Data Analysis System (ERDAS) Imagine 9.2 Software (ERDAS, 2013). A polynomial of 2^{nd} order (8 GCPs) is used for image-to-image registration. The nearest neighbor re-sampling method is used to calculate the pixels gray level values of the rectified output image. The accuracy of the correction process is evaluated by calculating the RMS error at 3 GCPs. The RMS error is the difference between the desired output coordinate for a GCP and the actual output coordinate for the same point, when the point is transformed with the geometric transformation. RMS error in X, Y directions and total (T) RMS error at the GCPs are calculated.

3.2 GPS measurements

The coordinates of GCPs and CPs were evaluated using GPS technology with two different processing techniques; GPS-Differential and GPS-PPP. GPS Differential technique gives the highest possible accuracy while GPS-PPP gives less accuracy comparing with GPS-Differential with lower cost and labor. The GPS observations were collected using Topcon GR-3 system (Topcon, 2013).

3.2.1 GPS-Differential

GPS-Differential positioning technique employs two receivers that track the same satellites simultaneously, one at reference station and the other at a rover (estimated) station. Some error sources can be eliminated by calculating the difference between the estimated and the known coordinates for the reference station and then employing corrections for the unknown station. The differential technique is used in surveying applications that need high accuracy. However, there are limitations in using differential mode, such as the dependence of the accuracy on the distance between the reference and rover stations. In addition, the need for at least two simultaneously operating receivers during data collection complicates field procedures and adds a great deal of expense.

The baseline length varies between 650 m up to 1800 m. At each station, Carrier phase and code observations were recorded at 15-second intervals for 30 minutes with the availability of at least four GPS satellites. Coordinates of 8 GCPs and 3 CPs were computed by post-process differential GPS. The positional accuracies obtained from different solution are shown in tables 1, 2 for GCPs and CPs.

3.2.2 GPS-PPP

Absolute positioning, also known as standalone, autonomous, or single point positioning, involves a single GPS receiver in non-differential mode. This receiver tracks four or more GPS satellites in order to determine its position relative to the reference frame of the known satellite orbits (usually GPS broadcast frame WGS84). It is possible to improve the accuracy of single point positioning with the availability of precise ephemeris and clock products from (IGS) and other organizations, the usage of both carrier-phase and code range measurements, and other corrections such as satellite antenna offset, ocean tide loading, atmosphere loading and site displacement effect. This technique is known as precise point positioning (PPP). PPP leads to positional accuracy at the centimeter or decimeter scale (PPP, 2012). The PPP solution for GCPs and CPs were provided using CSRS-PPP service (CSRS-PPP, 2012). The positional accuracies obtained from PPP-solution are shown in tables 1 and 2 for GCPs and CPs.

Table 1: The positional accuracies obtained from DGPS & PPP-GPS solutions for 8 GCPs

Data Source	DE (m)		DN (m)		RMSE (m)	
	Min.	Max.	Min.	Max.	Min.	Max.
DGPS	0.001	0.004	0.001	0.005	0.001	0.006
PPP-GPS	0.227	0.606	0.095	0.154	0.251	0.647

Table 2: The positional accuracies obtained from DGPS&PPP-GPS solution for 3 CPs

Data Source	DE (m)		DN (m)		RMSE (m)	
	Min.	Max.	Min.	Max.	Min.	Max.
DGPS	0.001	0.001	0.001	0.001	0.001	0.002
PPP-GPS	0.287	0.469	0.095	0.135	0.302	0.488

4. Results and discussion

The rectification processes were experimented using ERDAS Imagine 9.0 for both the satellite images, namely, Spot (2.5 m) and Geoeye (0.5 m). Spot image (2.5 m) was rectified using 8 GCPs whose coordinates were acquired using two techniques; DGPS and PPP. Table 3 shows the RMSE for 3 CPs resulting from DGPS and PPP for Spot image (2.5 m). Geoeye image (0.5 m) was rectified using 8 GCPs whose coordinates were acquired using PPP only. Table 4 shows the RMSE for 3 CPs resulting from PPP solution for Geoeye image (0.5 m).

Table 3: The RMSE for 3 CPs resulting from DGPS and PPP solutions for Spot image (2.5 m)

	CP No.	RMSE OF CPs (m)	
		DGPS	PPP
Spot Image (2.5 m)	1	5.97	1.91
	2	86.37	8.02
	3	75.44	19.62

Table 4: The RMSE for 3 CPs resulting from PPP solution for Geoeye image (0.5 m)

	CP No.	RMSE OF CPs (m) (PPP solution)
Geoeye Image (0.5 m)	1	1.47
	2	6.05
	3	7.32

For Spot image (2.5 m), the use of PPP solution for rectification process gives better RMSE for CPs comparing with DGPS solution. The deterioration in the RMSE of CPs directly related to deteriorated positioning accuracy for both solutions; DGPS and PPP.

For Spot image (2.5 m), the use of PPP solution for rectification process has improved the CPs' RMSE by (68%, 74% and 90%) with an average value of 77% comparing with the RMSE using DGPS. PPP solution is more common in collecting GPS observations due to its low cost and efficiency in labor and time.

PPP solution is producing a better behavior for rectification Geoeye image (0.5 m) compared to using the same technique for Spot image (2.5 m). The RMSE for CPs has improved by (23%, 25% and 63%) with an average value of 37%. The deterioration in the RMSE of CPs directly related to deteriorated positioning accuracy of PPP solution.

5. Conclusions

GPS technology can be used for rectification process when updated or appropriate-scale topographic maps are absent and highly accurate geometric correction is required. PPP-GPS solution provides high accurate geometric correction with efficiency in cost and time comparing with traditional DGPS. The rectification accuracy is directly proportional to the PPP-positioning accuracy. The percentage of improvement in RMSE using PPP-GPS solution over DGPS for Spot image (2.5m) reaches 77%. The PPP-GPS solution is offering high accurate geometric correction also for high resolution satellite image such as Geoeye (0.5m). The percentage of improvement in RMSE using PPP-GPS (Geoeye 0.5m) solution over PPP-GPS (Spot 2.5m) solution reaches 37%.

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Figure1: The Spot-5 image (2.5 m resolution) of the study area

Figure 2: The Geoeye image (0.5 m resolution) of the study area

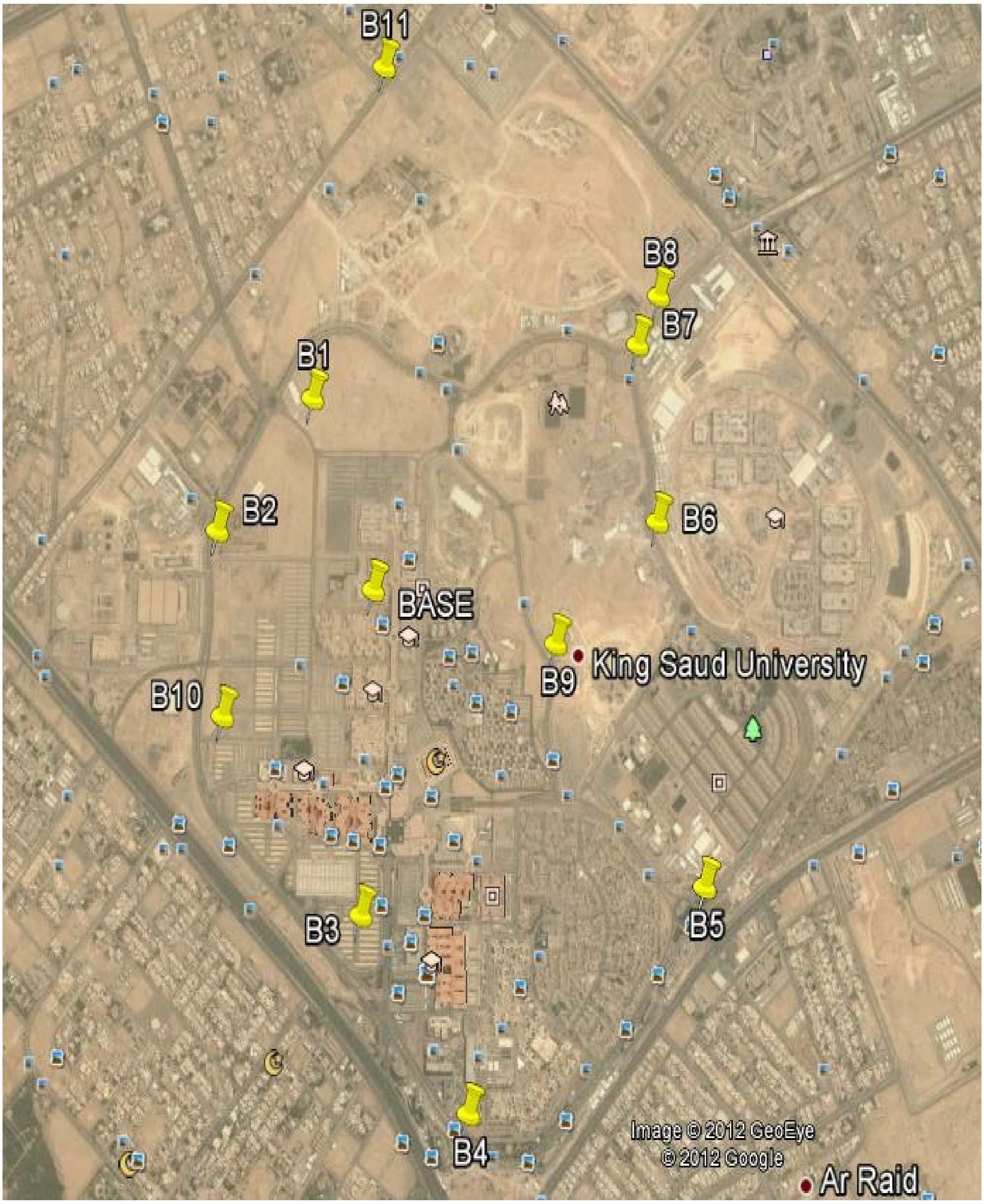

Figure 3: The distribution of the GCPs (Ground Control Points) in the study area (Image courtesy: googleearth.com)