THE ASSESSMENT OF HIGH RESOLUTION SATELLITE IMAGES AND APPLICATIONS IN REGIONAL AND LOCAL PLANNING

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ABSTRACT:

The establishment of database constitutes the most significant component of any GIS attempt. Saudi Arabia is a dynamic country with rapid structural changes in urban and rural areas whose areas amount to about 100,000 km2 and 2,100,000 km2 respectively. There are, however, very few topographic maps available to reflect these rapid changes. With the consideration of the time and cost of any terrestrial or photogrammetric project, it is wise to utilize mapping from space using high-resolution satellite images with resolution ranging from 15 m to 0.5 m.

For the establishment of the national geo database for telecommunication and planning purposes, LANDSAT-7 images and IKONOS / QuickBird images were acquired for rural and urban areas of S. Arabia. These images were rectified using proper DEMs and GCPs to an accuracy of about one pixel.

Landuse was derived from LANDSAT images and used for the rectification and geo-registration of structural plans of the entire country. IKONOS / QuickBird images amounting to 100,000 km2 were rectified using about 5 m precision DEMs (10 m grid spacing) and dm-precision GCPs taken at about 5 km spacing. For processing, we have used Russian Orthospace, Erdas Imagine, PCI and Hanover package. We have achieved an accuracy level of about 0.75 – 1.5 m, probably one of the best results obtained in commercial applications.

The results of the computations and the applications for telecommunication and planning studies are discussed in this paper. These images have constituted the foundation of geo-information for telecommunications and planning, including the establishment of a national Planning Information System (PIS) for the entire country. All the structural, local and subdivision plans have been integrated and registered with respect to these images.

1. INTRODUCTION

The establishment of graphical and non-graphical database constitutes the most significant component of any spatial information system attempt, as much as 90-95% of the total investment. Fortunately, there are modern techniques, such as space mapping, offering quick and economical solutions. This paper addresses applications of these techniques in the establishment of geoinformation database in Saudi Arabia.

Saudi Arabia is a dynamic country with rapid structural changes in urban and rural areas. There are, however, very few basemaps or high-resolution images available to reflect these rapid changes. Besides, local survey, mapping and subdivision activities lack any acceptable standard and format. They are, therefore, far from representing a great part of urban, even rural areas.

Owing to the reasons above and with the consideration of the time and cost of any conventional techniques, it is wise to utilize space technology to establish geo-referenced digital graphical (mainly orthophoto maps) database. Since applications like telecommunications and urban planning go down to the level of individual structure/parcel corresponding to a map scale of 1/10,000 to 1/5,000, the minimum requirement expected from urban imagery is:

a) a resolution 1-m or better
b) ortho-rectification to have map precision (e.g.: 1/10,000 to 1/5,000), i.e. to produce orthophoto maps

Since 2001, Saudi Telecom and Ministry of Municipal and Rural Affairs have launched several projects for the establishment of mapping database using HRS images. These projects covers:

- compilation of orthorectified HRS images (0.6 – 1.0 m) for an area of about 100,000 km^2
- compilation of orthorectified medium resolution satellite images (10 – 15 m) for the entire country, i.e. 2,000,000 km^2

Subsequent sections present technical information about HRS images, geoinformation database established using HRS images and results.

2. HIGH-RESOLUTION SATELLITE IMAGES (HRS)

A photogrammetric breakthrough has been realised by the use of space images. The earth observation started with photographic cameras used for national security reason (Lavrov, 2000). However, the first digital space camera system used in space, especially designed for unclassified mapping purposes was SPOT 1, launched in February 1986. It was followed by SPOT 2, 3, 4 and others such as IKONOS and QuickBird. More detailed information on space cameras, space images and space mapping can be found in Jacobsen (2001a,b).

The features of the satellites used in the projects subject to this paper are listed in Table 1. They play a very significant role as many countries have an intense need for detailed, accurate satellite imagery for a multitude of important applications, such as mapping, agricultural monitoring, resource management and urban planning. A brief discussion on IKONOS and QuickBird images, GCPs, DEMs and orthorectification is provided subsequent sections.

Figure 1. IKONOS image in Riyadh

Table 1. The main features of HRS used in our projects

	company or country	first launch	number of pixel	mode	pixel size (nadir)	swath [km]	pointing in-track	pointing across	height	orbit	storage
Quick Bird 2	Earth Watch	2001	27000 6700	pan multispr 4 bands 11 bit	0.61 2.44	17 17	+/-30°	+/-30°	450km	inclinat. 52	64 scenes
Ikonos active since 2000	Space Imaging EOSAT	failed April 99 success **Sept 99**	13816 3454	pan multisp. 4 bands 11bit	0.82 – 2.0 3.2-8	11.3	+/-45°	+/-45°	680	sun-synchr	64Gb
Resours 21	Resours 21	2001	2000	multisp 5 bands	10 20 MIR	205	+/-30°	+/-40°	743	sun synchr	176 Gb
SPOT 5	SPOT Image	2002	12000 6000	pan multisp 4 bands	2.5 10 20 MIR	30 60	+/-19.2°	+/-27°	830	sun-synchr	132Gb
Land-sat 7	USA	**since April 99**	1 16	ETM+ pan multisp 7 bands	15 30 60 TIR	185	--	--	705	sun-synchr	375Gb

2.1 IKONOS Images

The world's first commercial, high-resolution imaging satellite has been successfully launched on Sept. 24, 1999 from Vandenberg Air Force Base. The 720 kg IKONOS was launched into a sun-synchronous, near-polar, circular low-Earth orbit.

IKONOS is the first commercial imaging satellite of its kind. It simultaneously collects one-meter resolution black-and-white (panchromatic) images and four-meter resolution colour (multispectral) images. Designed to take digital images of the Earth from 400 miles (680 kilometres) up and moving at a speed of about four-and-a-half miles (seven kilometres) per second, the satellite camera can distinguish objects on the Earth's surface as small as one meter square in size.

One of the pictures of this satellite belonging to our project area is shown in Fig. 1.

2.2 QUICKBIRD Images

The QuickBird Satellite was launched on October 18th, 2001 at Vandenberg Air Force Base in California. The satellite is positioned at an Orbit altitude of 450 Km with an orbit inclination of 97.2°, sun-synchronous.

The QuickBird Satellite sensor provides Panchromatic (P) Image data at 11 bits with a pixel resolution of 0.61 m at nadir to 0.72 m at 25° off-nadir and MultiSpectral (MS) Image data at 11 bits with a pixel resolution of 2.44 m at nadir to 2.88 m at 25° off-nadir. The swath width of the QuickBird Satellite is 16.5 km at nadir. Pan sharpened Natural Color Standard or Ortho Image data is provided with a pixel resolution of 0.7 m.

The 0.61 m to 0.72 m Pan-sharpened Panchromatic or Natural Color products can be used for a wide variety of applications and represents the highest resolution satellite imagery currently commercially available. The satellite carries a state-of-the-art sensor and is the most advanced commercial imaging system in orbit.

One of the pictures of this satellite belonging to our project area is shown in Fig. 2.

Figure 2. QuickBird image in Riyadh

2.3 Ground Control Points (GCPs)

In the orthorectification of HRS images, GCPs play very significant role. For IKONOS and QuickBird images, GCPs were established to dm-level accuracy at a spacing of about 5 km. In case of LANDSAT-7 images, GCPs were established to m-level accuracy at a spacing of about 50 km.

In order to establish GCP archive to be used in future, for each GCP, a description card was prepared and in many cases photos were also taken at these points from a short and medium range. The coordinates of GCPs were determined in the national datum (Shedayed et al., 1992) as well as the WGS84 datum.

2.4 Digital Elevation Models (DEMs)

It is to be noted that the IKONOS Geo product and QuickBird Basic and Standard Ortho Ready Imagery Data requires to be processed with the refined **I**mage **S**upport **D**ata (**ISD**) set, including the orbital parameters of the sensor, GCPs and a **D**igital **E**levation **M**odel (**DEM**), to obtain the Image accuracy at the level of 1.0 – 1.5 pixels.

The accuracy and resolution of the DEM required for the orthorectification of the Satellite Images is depending on the Image georeference position accuracy specified by the Customer. Since it is aimed to have 1.0 – 1.5 pixel accuracy in our projects, a DEM with an accuracy of at least 5 meters is required.

2.5 Orthorectification

The system corrected satellite images are subject to errors and distortions due to height differences and lack of precise ground control points. These errors may be as big as 50 meters in case of the system corrected HRS images depending on the magnitude of vertical angle and topographic relief. As part of this project, the orthorectification of IKONOS and QuickBird images to 1.0 – 1.5 pixels was performed very successfully. The orthorectification process was carried out using Russian OrthoSpace, which uses a dynamic model without requiring sensor camera parameters and / or PCI with sensor parameters and rational polynomial coefficients. The mosaicking was carried out using IRAS-C software.

3. SAUDI GEODATABASE USING HRS IMAGES AND PLANS

3.1 Image Geodatabase

Using HRS images, a very comprehensive geodatabase was established. It consists of about

- 100,000 km^2 of IKONOS and QuickBird images (Fig. 3)
- 2,000,000 km^2 of LANDSAT-7 images (Fig. 4)
- structural plans of the entire Saudi Arabia
- local plans and subdivisions of Qaseem, Riyadh and Aseer regions (Fig. 5)

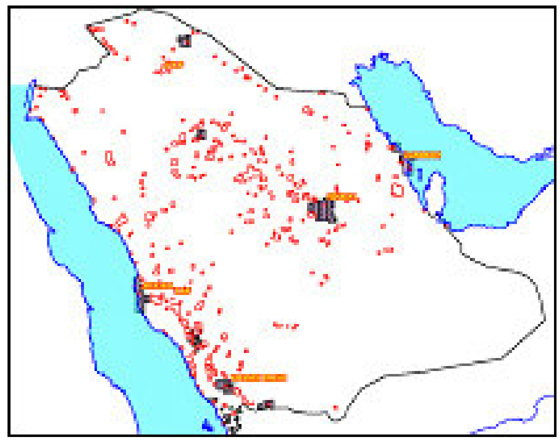

Figure 3. IKONOS & QuickBird coverage (100,000 km2)

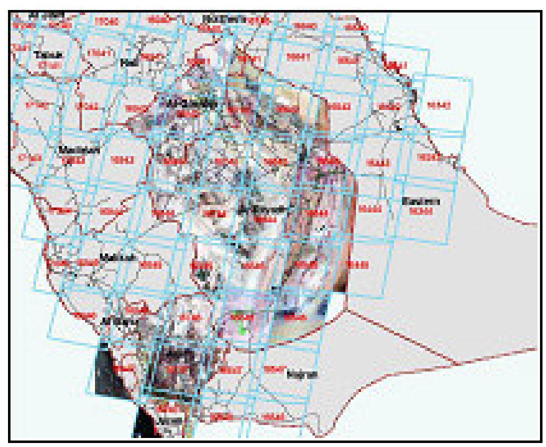

Figure 4. LANDSAT-7 and structural plans coverage (2,000,000 km2)

Figure 5. Local plans coverage (840,000 km2)

The LANDSAT-7 images were orthorectified using GCPs spaced at about 50 km spacing and DEMs of 30 m postings. A geometric accuracy of about 15 – 20 m was achieved. The landuse of about 20 categories were derived using these images.

The IKONOS and QuickBird images were orthorectified using GCPs spaced at about 5 km spacing and DEMs of 10 m postings. A total of about 6000 GCPs were established. A geometric accuracy of about 1.0 – 1.5 m was achieved. This is probably one of the biggest and most successful projects solving the need of fundamental geodatabase of a country.

A seamless database of 100,000 km2 was established using orthorectified IKONOS and QuickBird images. Thus, Saudi Arabia has a very reliable, georeferenced and complete HRS image database which will be the foundation for other spatial data such as telephone network, land database, planning, etc.

The orthorectified IKONOS & QuickBird images were checked by the Consultant of the project independently. For checking purposes 9-16 uniformly distributed points were picked in 9 areas covered by IKONOS images. These points were GPS surveyed and these coordinates were compared against those read from orthorectified images. The RMS values obtained from comparison are tabulated in Table 2. The overall RMS value of comparison is 1.59 m. The tests in other areas are under progress.

Table 2. Orthorectified IKONOS test results

REGION	**AREA (km2)**	**Number of Test Points**	**RMS ERROR (m)**
Najran	1620	8	2.02
Gizan	2205	9	1.59
Aseer	3050	15	1.79
Baha	1600	12	0.88
Hail	1010	9	1.04
Arar	1750	13	1.33
Riyadh	7330	12	2.29
Jeddah	4840	14	1.32
Dammam	4370	16	1.60
		108	**1.59 m**

First, possible DEM collection techniques were examined, including using Russian TK-350 stereo photographs (Fomtchenko et al., 2000). Since our tests have not yielded satisfactory results, we decided to use existing topographic maps. The DEMs used in the orthorectification of IKONOS & QuickBird images were compiled from topographic maps of 1/10000 – 1/50000 depending on the roughness of the topography. The compiled DEMs were checked by external control measurements For this purpose, a total of 1242 checkpoints / GCPs which have height accuracy better than 1 m. These heights were compared against those obtained from DEMs' database. The RMS values obtained from comparison are tabulated for each area in Table 3. The overall RMS value is 6.48 m. Additional tests and comparisons are under way.

Table 3. IKONOS / QuickBird DEM areas and test results

Area / Region	Area (km2)	Number of Check Points	RMS values of DEM checking
Najran	1620	50	2.54 m
Gizan	2205	147	7.34 m
Aseer	3050	95	8.02 m
Baha	1600	231	6.90 m
Hail	1010	69	7.18 m
Riyadh	7330	212	6.83 m
Jeddah	4840	255	5.66 m
Dammam	4370	77	4.64 m
Arar	1750	106	5.74 m

3.2 Planning Geodatabase

Ministry of Municipal and Rural Affairs is responsible for planning of Saudi Arabia. The Ministry had structural and local plans, all as hardcopy and lacking acceptable geometric accuracy, standard and format. One good example to this problem is illustrated in Fig. 6. Over 2000 structural plans, which covers the entire S. Arabia (13 regions), were digitized and georegistered using existing topographic maps and LANDSAT-7 database mentioned above.

As can be seen in Table 4, For 3 regions, namely Qaseem, Riyadh and Aseer (see Fig. 5), over 29,000. km2 of IKONOS and QuickBird images were used to i) update structural plans of 685 sheet (see Table 5) ii) rectify local and subdivision plans of 619 sheet (see Table 6).

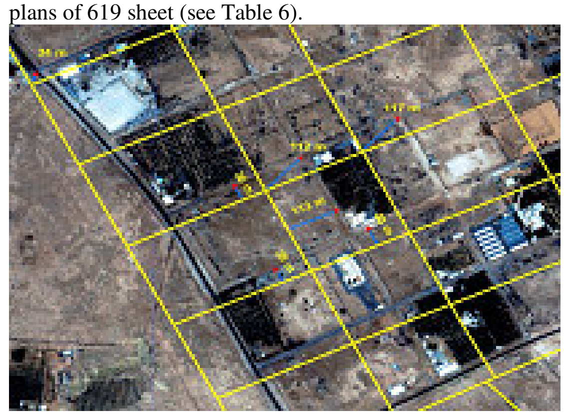

Figure 6. An existing local plan against IKONOS image

Table 4. Ikonos / QuickBird Satellite Images Used

REGION	Ikonos/QuickBird Coverage km^2
Aseer Region	**8,926**
Al-Qaseem Region	**5,218**
Riyadh Region	**15,178**
TOTAL	***29,322***

Table 5. Total Number of Structural Plans processed

REGION	Hardcopy	Rectified
Aseer	**280**	**169**
Al-Qaseem	**243**	**158**
Riyadh	**516**	**358**
TOTAL	***1039***	***685***

Table 6. Total number of local plans / subdivisions processed

REGION	Hardcopy	Rectified	*Area Km^2*
ASIR	**358**	**199**	**113**
QASSIM	**661**	**246**	**95**
Riyadh	**373**	**174**	**93**
TOTAL	***1392***	***619***	***301***

4. PLANNING INFORMATION SYSTEM (PIS) APPLICATIONS AND GTVS

A comprehensive geodatabase, consisting of rectified images and plans together with their associated attribute data, was created on the ESRI platform and Planning Information System of MOMRA (MOMRA-PIS) was established. . User friendly application programs were developed for Server, Intranet and Internet applications in order to carry out basic query, search, view, analysis and output. Some examples to the output of MOMRA-PIS can be seen in Figs. 7a, and 7b.

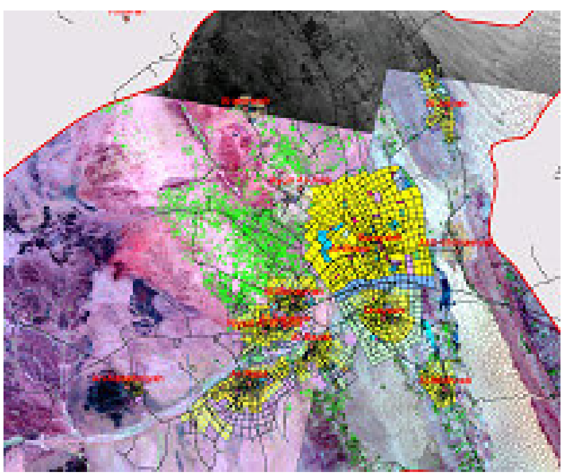

Figure 7a. An example to MOMRA-PIS

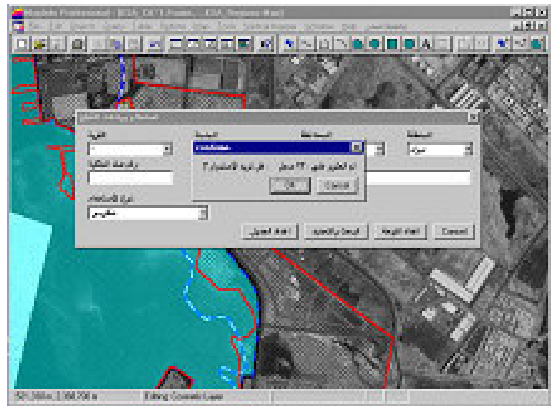

Figure 7b. An example to MOMRA-PIS

Digital **E**levation **M**odels (**DEMs**) can be utilized in support of 3D Terrain Visualization and Modelling. We have developed a powerful package called, Geotech Terrain View Suite (GTVS), to create 3DTerrain conditions with manually Flythrough capabilities providing the user with a good decision tool for the planning of local and regional projects (www.gtvs.net).

5. RESULTS

There is lack of geographic data in some Middle East Countries. For this reason and with the consideration of the time and cost of any terrestrial or photogrammetric project, it is wise to utilize space technology to establish geodatabase. Satellite imagery is a good resource for precision mapping in these countries. Thus, this project is a successful example and shows a simple but powerful solution to developing and even developed countries lacking up-to-date database and GIS operations.

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