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New remote sensing sensors and imaging products for the monitoring of urban dynamics

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ABSTRACT: For about two years new sensor system imaging products are available providing digital images with a new quality. On the one hand the spatial resolution has increased, on the other hand the repetition rate has also been increased. Aerial scanners acquire digital multispectral images and provide digital surface models (DSM). These imaging products can be used for a detailed monitoring of urban dynamics. The georeferenced orthoimages can be readily integrated into GIS. New spaceborne sensors provide a ground resolution of about 0.61m (pan) and 2.44m (ms) with an effective repetition cycle of three days, which makes them suitable for a near real time monitoring of urban changes.

1 INTRODUCTION

For a detailed monitoring of the multifarious urban features aerial photos are a reliable and well proofed information with some advantages. These imagery are acquired at a very large scale up to 1:3000. Visible true-color photos are taken for cadastral and surveying purposes in late spring, before leaves on trees conceal the ground. The date of acquisition is a compromise between a sufficient solar angle and the stadium of tree vegetation. Color-infrared photos (CIR) are taken in summer for the purposes of vegetation health studies, the establishing of tree-cadastral etc. Aerial photos have been used over decades in urban administration and so they become a standardized system for the documentation of urban dynamics. The techniques improvement of aerial photos is an ongoing process while the price becomes lower over the time for these products.

Disadvantages of aerial photos are the moderate spectral resolution (CIR or vis-color mode), the low radiometric resolution of about 30 gray - values per band (Albertz 2001). At least the low temporal resolution or repetition cycle of 3-5 years in Germany is a too long for a reliable documentation of the very fast changes especially in urban areas.

The most evident disadvantage of aerial photos is the analog acquisition of image information, which can not be integrated into a Geographic Information System (GIS) environment. But nowadays most monitoring processes are basing on digital cadastral or cartographic data. For the use of aerial photos in a GIS as an orthophoto a work- and cost-intensive process has to be applied to these images.

2 NEW IMAGING SENSORS

2.1 *Digital airborne sensors and imaging products*

In the series of optical remote sensing digital airborne sensors are the last segment (Fig. 1).

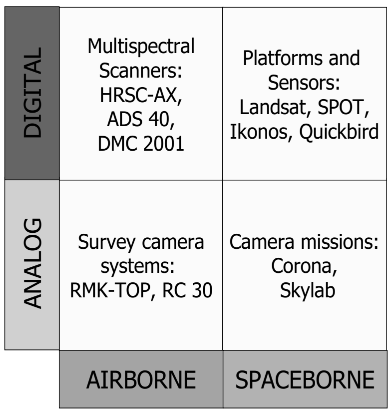

Figure 1. Classification of optical remote sensing sensors (from ll to ul).

The imaging products of the first generation of new airborne sensors are available since the year 1999 (Möller 2000). The most important representative of the first generation scanners is the High Resolution Stereo Camera - Airborne (HRSC-A). The pushbroom scanner provides panchromatic imagery with an extremely high ground resolution of 0.15m and multispectral data with a physical resolution of 0.3m (according to a flight altitude of 3000m above ground level). In addition a Digital Surface Model (DSM) with a pixel-size of 0.5m is derived from two forward and backward facing stereo-sensors. Parallel to the image acquisition the aircrafts position and rotation angles are stored by Differential Global Positioning System (DGPS) in combination with an Inertial Navigation System (INS). These data provide the very high geometric accuracy of ± 0.15m in x- and y-direction and 0.2m in z in the process of photogrammetric georefencing.

Since 2001 the second generation of airborne scanners with advanced technology is successfully tested by the German Space Center (DLR), the developers of the HRSC-AX, X stands for extended version (Neukum 2001). Leica-Helava (LH-Systems) has its own camera project, the Airborne Digital Scanner (ADS40), also a pushbroom scanner (Fricker 2001). ZI-Imaging developed a dot-matrix scanner, the Digital Modular Camera (DMC) (Hinz et al. 2001).

All of these sensors provide in-flight stereoscopy, direct georefencing and a spectral bandwidth ranging from vis to ir in four bands. The radiometric resolution is 12 bit (Table 1). Both LH-systems and ZI sell the complete system consisting of the scanner, the DGPS/INS unit and the data storage facilities on board the aircraft. The data processing has to be done by the customer with special software. The HRSC image-data is processed by the DLR and its reseller ISTAR, France.

Table 1. Second generation of new airborne sensors.

system	HRSC - AX	ADS 40	DMC 2001
developer	DLR	LH-Systems	ZI
imaging principle	Pushbroom	Pushbroom	Matrix
CCDs per line (pan/ms)	12000	12000 2*12000	3000*2000 13500*8000
size of CCDs (µm)	6.5	6.5	ns
CCD lines (ms bands)	9 (4)	7 (4)	8 (4)
focal length (mm)	151	62,7	125 (pan), 25 (ms)
FOV	28.9°	64°	74°*44° (x,y)
blue (nm)	450-510	430-490	blue
green (nm)	530-576	535-585	green
red (nm)	642-682	610-660	red
infrared (nm)	770-814	835-885	infrared
pan (nm)	520-760	465-680	pan
frequ. (Hz)	1640	---	0,5 (Matrix)
rad. res. (bit)	12	12	12

ns - not specified

The image data of these sensors are delivered very fast after photogrammetric geometric correction to the customer. The geotiff-format of the processed image-data contains the projection-parameters and geo-coordinates and the images are delivered GIS ready to the customer.

The price for airborne imagery depends strongly on the covered area and the amount of processed data, which decreases with a higher flight altitude and a coarser resolution. The price varies between 150-300€ per sqkm for all three products (pan, multispectral and DSM). A typical German city with about 150.000 residents and an administrative area of about 120km² with additional overhead area of 80km² in the surroundings may cost up to 30.000-60.000€.

2.2 *Digital spaceborne sensors and imaging products*

Spaceborne imagery with a panchromatic ground resolution of 0.61m and 2.44m multispectral will be available from the Quickbird sensor. Since 1999 a series of high resolution satellite sensors has been launched and in the next future more of these systems are expected (Table 2).

Table 2. High resolution spaceborne sensors.

company	EarthWatch	Space Imaging	Imagesat International
systems name launched in	Quick Bird 2001	Ikonos 1999	EROS A1 2001
mode	ms 11 bit	ms 11 bit	pan 11 bit
res. (m) pan/ms	0.61/2.44	1.0/4	1.8
bandwidth in nm pan	450-520 520-600 630-690 760-900 450-900	450-520 520-600 630-690 760-900 450-900	 500-900
swath width (km)	16.5	11/22 pan	12.5
orbit height (km)	450	681	480

Both Ikonos and Quickbird provide four visible and infrared multispectral bands and one panchromatic band just in the same bandwidth of Landsat Thematic Mapper (TM) satellite sensor. The TM sensor is good for environmental studies, especially band three and four (red-ir) are used for the calculation of vegetation indices (Sabins 1997).

The panchromatic band in combination with the multispectral bands can be used for the calculation of a ‘pan-sharpened’ imagery. On the one hand these imagery provide the detailed and very high resolution information of the pan-band and on the other hand the visible or infrared multispectral information.

The image data can be ordered at several processing levels and different prices. The price is strongly correlated to the geometric accuracy. The GEO product for an Ikonos image taken over Europe costs 30US$ for the pan image product, 30US$ for the multispectral image and 40US$ for a bundle of both image-types. A minimum area of 100km² has to be ordered. This leads to costs up to 6000US$ for the acquisition of a complete multispectral coverage for the typical city.

The sensors can be rotated out of the nadir view to guarantee a side looking angle up to 45°. This increases the repetition cycle up to 3 days for every place on earth. The online ordering over the internet increases the time of data acquisition until the data is delivered to the customer.

3 APPLICATIONS OF NEW SENSORS IMAGING PRODUCTS

Digital airborne images with the extremely high ground resolution to new user demands. A number of operational applications in the context of urban monitoring have been developed over the last years depending on these data.

3.1 *Applications of airborne scanner imagery*

3.1.1 *Online data access through the internet*

The most important feature of airborne scanner imagery is the digital format of the georeferenced data. The data can be electronically distributed by the internet online or other media like CDs offline. With a common browser interface, everybody connected to the internet, may easily browse and –if desired- download the data of interest directly on the desktop PC. Everybody may use the data for own purposes, either in a common image visualization software or in a complex GIS environment. This guarantees a large growing number of potential users compared to that of analog aerial photos. The online accessibility of digital georeferenced image data for a complete administrative area of a large city has been realized for the first time in 1999 for the City of Osnabrueck basing on images of the HRSC-A (Möller 2000).

The digital images can be integrated into the structure of an online city-map or an Urban Information System (UIS) as a basic information.

3.1.2 *Data output as an analog map*

In some cases analog, printed maps are even now the best source for a reliable geographic information. The HRSC data have been used for a orthophoto-map of Berlin, Germany. The map at a scale of 1:5000 was created by Hoffmann & Lehmann (2001) for the Senate of the City of Berlin.

3.1.3 *Digital image enhancement*

Due to the high radiometric resolution the digital airborne scanner data provide more information compared to analog scanned photos. Using a special edge-enhancement-filter very detailed urban structures can be enlarged (Fig. 2a and 2b). In this case a 5*5 filter successfully tested by Jensen (1986) was applied on the data.

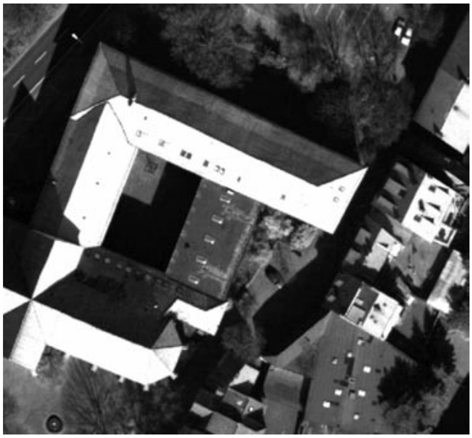

Figure 2a. Original 0.15m HRSC-A nadir image (size: 135*120m)

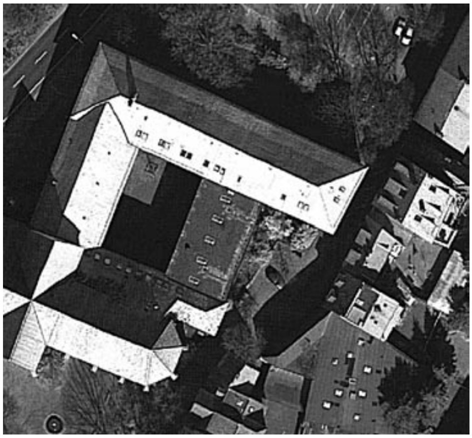

Figure 2b. Filtered HRSC-A nadir image

3.1.4 *Multispectral visual and automated analysis*

The original and enhanced images are a good source for a visual interpretation especially for cadastral and surveying purposes in urban areas. Vegetated urban areas belonging to the community have to be kept in shape by the community's administration. Therefore a reliable base-information regarding area-size and the vegetation type has to be stored in a UIS. This information can be extracted completely from the airborne scanner imagery.

Another important information for urban planners is the number of vegetated roofs, especially in inner cities. Vegetation is essential for a well-balanced urban climate. Using an automated approach, the number of vegetated roofs for the whole city can be extracted from the spectral HRSC-A pan and ir band-information (Möller 2001).

3.1.5 *DSM - DEM - OHM*

The height information becomes more and more essential for planners especially in urban areas. Emission-pattern of electronic or acoustic waves can be simulated for mobile communication purposes or for the spread of traffic noise.

The HRSC-A DSM can be used with the corresponding visible image for the extraction of terrain elevation and object height. In a first step a number of points representing the terrain level have to be digitized interactively from the vis image in a GIS. In a second step the points are attributed with their specific height value from the DSM. In a last step an interpolation has to be performed on these points using Inverse Distance Weighting (IDW) algorithm. The resulting Digital Elevation Model (DEM) is from a good geometric accuracy compared to the official DEM of the surveying office Lower Saxony (LGN).

The outlines of buildings are stored in the official digital cadastral map data (ALK) as a 2-dimensional data-set. The height above ground is not recorded until now, but for 3D visualization purposes the height has to be assigned to every building. We used the centroid, the geographical center of every building, as a representative point for the overall height of each building. For these points the difference DSM minus DEM is calculated and the resulting value is assigned as an attribute to the cadastral data. Figure 3 shows the DEM and the buildings in a 3D vision.

Figure 3. Perspective 3D-view of a 3*3km² area in the SW of the City of Osnabrueck; heights extracted from HRSC-DSM.

3.2 *Spaceborne Imagery*

Spaceborne imagery provide a short repetition cycle up to 3 days, which is useful for the monitoring of actual changes in a near real time observation mode. Damage control and the documentation of natural hazard impact is the field of operational application for these imaging products. The first Ikonos image of the damage of the Trade Center Towers was taken by Space Imaging corp. 4 days after attack.

The side looking angle may lead to huge image distortions especially for large objects. A first image of the Quickbird sensor gives an impression of the quality of these images (Fig. 4). For an urban change detection monitoring, a nadir view angle is strictly recommended. This will guarantee the correct overlay and geometric fitting with other geo-related data in a GIS environment.

Figure 4. Quickbird image of San Francisco, California, 0.61m resolution, Digitalglobe©.

4 CONCLUSIONS

The new generation of airborne and spaceborne sensors show a great potential for the monitoring of urban changes.

Airborne imagery are from an extremely high resolution and of high geometric accuracy. This makes them useful for a number of operational cadastral and surveying applications. The imagery can be interpreted by on-screen digitizing and also by automated methods with appropriate image analysis software. The DSM-data can be used as a reliable source for the interactive extraction of terrain elevation and object height.

The most important improvement of spaceborne imagery is the fast repetition cycle which leads to an impressive potential for a near real time monitoring of natural or man made hazards.

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