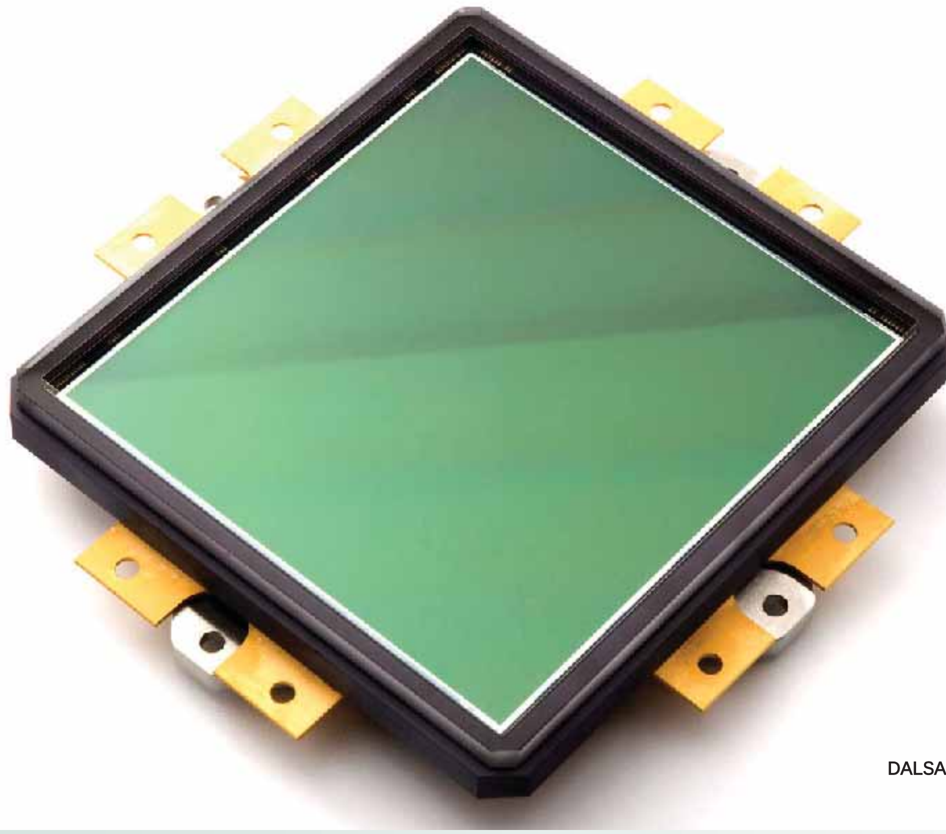
IMAGES OF CHANGE



DALSA CCD-array with 17216 x 14656 pixels

PHOTOGRAMMETRY HAS BEEN WITNESSING CONTINUOUS DEVELOPMENTS IN TECHNOLOGY EVER SINCE THE SHIFT FROM ANALOGUE TO DIGITAL FORMAT. HERE'S A LOOK AT SOME RECENT DEVELOPMENTS

Photogrammetry has been witnessing continuous developments in technology ever since the shift from analogue over analytical to digital photogrammetry. Images may be taken from space, air or ground. Not only classical images, but radar images or information are also being used. Computer vision is having increasing influence, especially in automatic object recognition and image matching.

Globalisation is strongly influencing traditional photogrammetric companies in several countries that are not able to compete for manual data acquisition with companies in areas with lower salaries, causing increase in request for automation of data acquisition. The former clear distinction between space and aerial photogrammetry has disappeared. With ground resolution down to 0.5m, space and aerial applications are overlapping and the selection decision between them is just based on economic aspects and availability of images. Restrictions for aerial images in some countries have been bypassed by space images.

SPACE PHOTOGRAMMETRY

High resolution imaging capacity has been strongly enhanced. By theory, with better ground resolution, GeoEye-1 and WorldView are able to image up to 700,000 km^2 and 975,000 km² per day - six to seven times more than IKONOS and QuickBird. With a system of five satellites, Rapid Eye can cover 6.5m ground sampling distance (GSD) by theory, nearly any location on the world every day. Table 1 shows theoretical imaging capacity of some very high resolution optical satellites. Fig. 1 depicts high resolution satellites with ground resolution and launch time.

Large image archives exist and with the availability of a high number of satellites, placing an order for actual imaging is not a problem. Nevertheless, optical satellite imaging still depends on cloud coverage which is not the case with radar satellites. For civil applications, high resolution radar images with 1m GSD can be used. Of course 1m GSD in an optical image cannot be compared to 1m GSD in a radar image. Interpretation of radar images is more complicated as compared to optical images. Under usual conditions, the information content is not as high. Especially in urban areas, lay over effects and viewing shadows limit the detailed use of radar images. However, for rapid response radar has strong advantages.

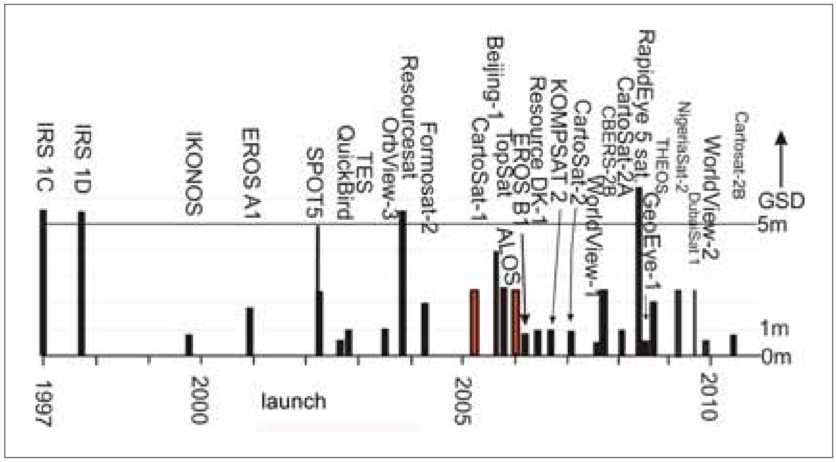


Fig. 1. High resolution satellites with ground resolution and launch time

A bottleneck in mapping is the requirement of ground control points (GCPs). With WorldView and GeoEye-1, the absolute geo-reference quality without the use of GCPs is in the range of 3m, meeting requirement for several purposes. This is an improvement by the factor of three over IKONOS and QuickBird. The geo-reference of radar images only depends upon the satellite position and not altitude as is the case with optical satellites. With TerraSAR-X-images, even a higher level of absolute geo-reference can be achieved if satisfactory height models are available. Fig. 2 presents a TerraSAR-X spotlight image of Leibniz University Hannover with 1m GSD.

A major application is the generation of height models. With the SRTM and ASTER GDEM height models, coverage of nearly the entire world is available free of charge. Fig. 3 shows the area covered by ASTER GDEM and SRTM C-band DSM. However, the partially high number of stereo scenes used are not horizontally adjusted to each other, causing a loss of geomorphologic details. By a re-computation, this shall be improved and will deliver geomorphologic details corresponding to the point spacing. Nevertheless, the SRTM height model has a better geo-reference, is more homogenous and is as accurate as the current ASTER GDEM. Height models gener-

Satellite	Collection rate	Approximate theoretical collection capacity / day
IKONOS	2365 km²/min	150 000 km²/day
QuickBird	2666 km²/min	135 000 km²/day
OrbView-3	1483 km²/min	80 000 km²/day
WorldView-1	4512 km²/min	750 000 km²/day
GeoEye-1	2842 km²/min	pan: 700 000 km²/day; pan+ms: 350 000 km²/day
WorldView-2	4686 km²/min	975 000 km²/day

Table 1. Theoretical imaging capacity of some very high resolution optical satellites

Fig. 2. Leibniz University Hannover, TerraSAR-X spotlight image, 1m GSD

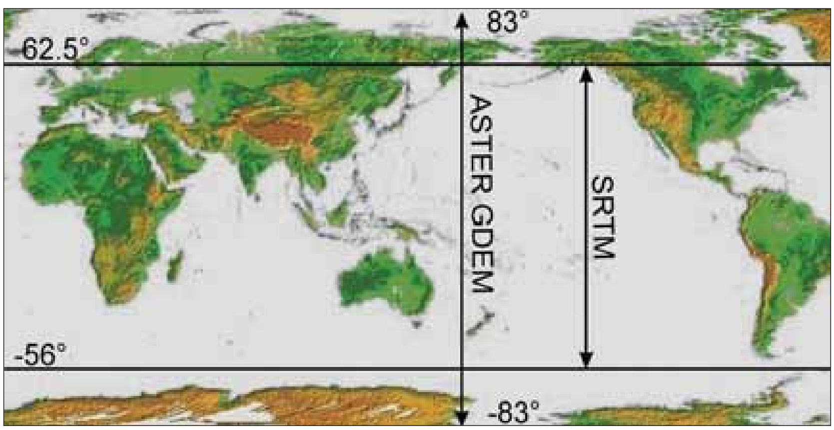


Fig. 3. Area covered by ASTER GDEM and SRTM C-band DSM

ated by optical space images should be based on images taken at nearly the same time. This is possible due to the very flexible, high resolution space sensors from the same orbit. However, the required satellite rotation reduces the imaging capacity drastically, so only a limited number of stereo scenes taken by very high resolution sensors are in the archives. A better solution is the use of stereo sensors as Cartosat-1, ALOS PRISM and SPOT HRS. The spectral range of SPOT HRS is limited to the visible range, causing low contrast over forests. Here, both other sensors have advantages in addition to the two times enhanced GSD. While ALOS PRISM's three view directions improve point determination against two view directions of Cartosat-1 and SPOT HRS, ALOS PRISM is not really made for commercial application. This leaves Cartosat-1 as an optimal tool for the generation of precise height models.

As has been shown by SRTM, good height models can be generated with radar interferometry. Now with TanDEM-X and TerraSAR-X, flying together in tandem-configuration, qualified digital surface models (DSM) will be generated. Fig. 4 shows a colour coded DSM.

With new technologies such as semi global matching (SGM), initiated by computer vision with 0.5m to 1m GSD images, high quality 3D-city models can be generated. A comparison of 3D-city models with IKONOS, GeoEye and aerial photo stereo pairs gave satisfying results, while the results with scanned aerial photos with 70cm GSD were not optimal. Of course this would be different with original digital aerial images not affected by film grain as scanned photos. The generation of topographic maps with space images is limited by information contents and not accuracy. Intensive studies have shown that images with 0.1mm GSD in the map scale are required for the identification of necessary object details. This corresponds to a map scale 1:10,000 for 1m GSD or 1:5000 for 0.5m GSD. With the announced 0.33m GSD of Cartosat-3 or 0.25m GSD of GeoEye-2 mapping, even a larger scale will be possible in near future.

AERIAL PHOTOGRAMMETRY

Digital aerial cameras have now replaced analogue film cameras. A comparison of details for topographic mapping from digital images with

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Z/I Imaging DMC, Vexcel UltraCAM and Leica Geosystems ADS40 images as well as scanned aerial photos, with similar ground sampling distance, revealed that just 8520^2 pixels are required for the information contents of scanned aerial photos in relation to original digital images not degraded by lower effective resolution. Till the year 2010, an information content corresponding to aerial photos was only possible with digital system cameras such as Ultracam and DMC or line scanning cameras such as ADS80 and Jena Optronic JAS-150. The dream of photogrammetrists to replace the film with just one large CCD-array has now become a reality. Depending upon the version, with very large size CCDs, the panchromatic band of the DMC II has between 140 and 256 megapixels from one CCD with excellent image geometry and radiometry. The panchromatic channel of the DMC II 250 uses a DALSA CCD-array with 17216 x 14656 pixels and can be operated with a frame rate of 1.7 sec. No stitching is required for such a monolithic camera. Tests of the DMC II 140 showed an excellent geometry with systematic image errors in the root mean square below 1 micron. Large format area and line scan cameras have four spectral bands - blue, green, red and near infrared, allowing a multispectral object classification. Nevertheless, the dominating aspect of aerial images is the texture. In addition to multispectral information, all satisfying classifications also use texture layers.

In aerial photogrammetry, not only large format digital cameras but several mid-format cameras are also

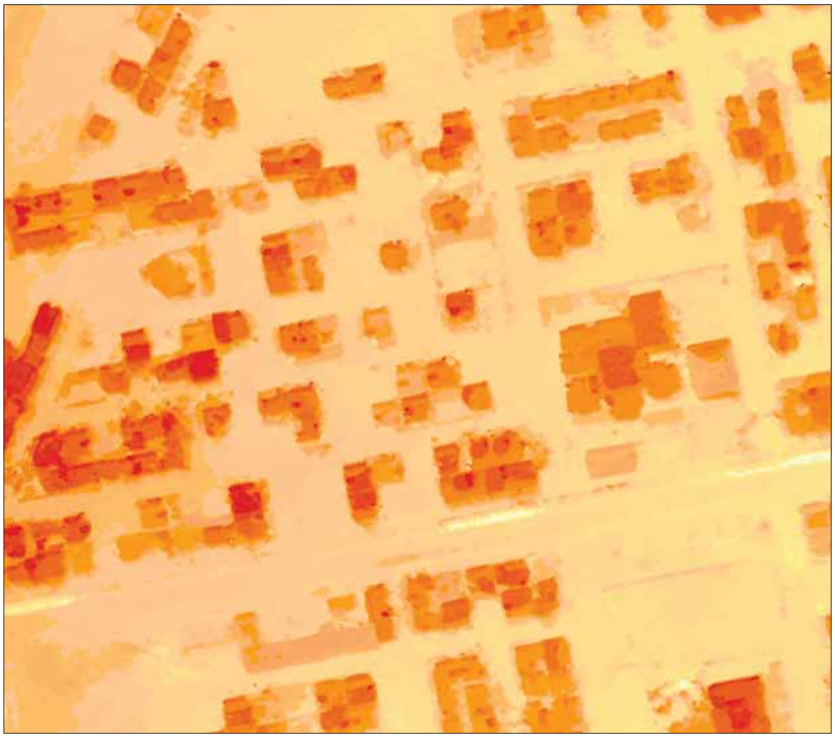

Fig. 4. Colour coded DSM

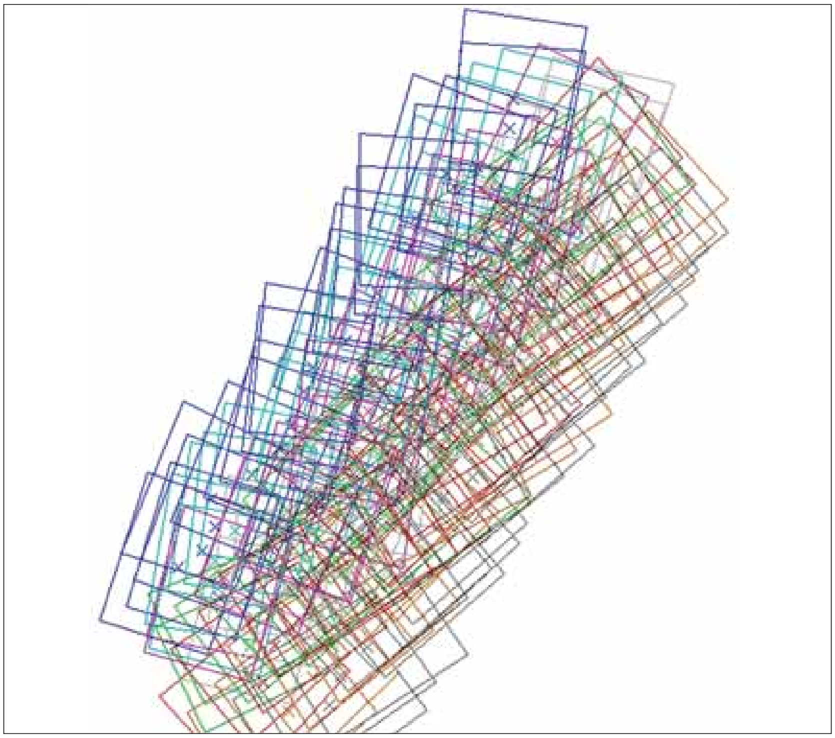

Fig. 5. Block flown with a UAV

Fig. 6. Automatic road extraction in IKONOS image

used. With modern CCDs, they can have a capacity of up to approximately 8900 x 6700 pixels. With the exception of the system cameras from Z/I Imaging and Vexcel, the mid-format cameras receive colour information with a Bayer pattern - they use just one CCD-array with individual RGB filter in front of any pixel, producing RGB images by complex computation. With Bayer pattern it is not possible to get four colour channels and forward motion compensation by electronic transfer delay and integration technology, as is the case in large format frame cameras. Only DIMAC equips its mid-format camera with mechanical forward motion compensation. With lower price level, mid-format cameras find applications mostly in smaller projects, but in general their geometric quality has some limitations. Also, systems of mid-format cameras, eg IGI Quattro DigiCam use a configuration of four slightly convergent arranged DigiCams. Such systems need support of GPS or GPS and IMU to solve image orientation without large number of control points.

> The use of unmanned aerial vehicles is extending fast, due to improved cost benefit relation and navigation support

The use of unmanned aerial vehicles (UAV) is extending fast, due to improved cost benefit relation and navigation support. In several countries, weight limits for UAV call for small systems. To address this, the company BLOM built a UAV weighing just 0.5 kg, equipped with a tiny camera with 3072 x 2304 pixels with 1.7 microns pixel size and 5.9 mm focal length. Of course the navigation of such UAVs is difficult under windy conditions, but blocks even with higher overlap can be flown, giving a good overview over the project area. Fig. 5 depicts a block flown with a UAV.

AUTOMATIC OBJECT EXTRACTION

Automatic object extraction from space and aerial images has been, for a long time, an intensive field of research. So far it is not possible to reach the quality of a human operator, but the speed of mapping or quality assessment of mapping can be increased by operator supported object extraction. It is possible to identify the quality of automatic object extraction. A traffic light system has been developed by Leibniz University, Hannover. In this system, shown in Fig. 6, a clear identification of roads is marked in green, doubtfully identified roads are marked in yellow and roads which have to be checked by the operator are shown in red. This system is in practical use and reduces the operation time significantly.

Karsten Jacobsen
Institute of Photogrammetry
and Geoinformation
Leibniz University, Hannover
jacobsen@ipi.uni-hannover.de