INFORMATION CONTENTS OF ORBVIEW-3 FOR TOPOGRAPHIC MAPPING

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ABSTRACT:

The very high nominal ground resolution of OrbView-3 indicates the possible use for mapping up to the map scale 1 : 10000. For OrbView-3 the pixel size projected to the ground is not identical to the ground sampling distance (GSD) – the distance of the neighboured ground pixel centres. By this reason the possibility of object point identification has to be checked in relation to IKONOS-scenes having the same nominal GSD. But nevertheless IKONOS usually only is distributed with 1m GSD even if the physical GSD is 0.82m for nadir view, so the image quality of IKONOS may be better like for OrbView-3. Of course the comparison of just one OrbView-3 image with IKONOS has only a limited meaning because of a possible influence of the actual imaging conditions like sun elevation and situation of the atmosphere, but at least it is indicating the mapping possibility. A simple check of the effective image resolution can be made by edge analysis. This still has to be verified with a map generation to show the real limitations of object identification.

1. INTRODUCTION

The very high resolution satellite images have become important for topographic mapping since the improvement of geometric resolution to 1 m or better. In addition the radiometric resolution is improved to 11 bit. OrbView-3 is one of the recent very high resolution space sensors operating at 470 km altitude since June 2003. It has a panchromatic channel with 1 m resolution and four multispectral channels (red, green, blue and near infrared) with 4m resolution, but the panchromatic and the colour channels cannot be used together.

For mapping the geometric accuracy and the information contents are important. The geometric accuracy of the high resolution images is usually not the limiting factor for topographic mapping. Well defined points can be determined with a standard deviation of the object coordinates better than one ground sampling distance (GSD) – the distance between the projected pixel centres (Jacobsen et al, 2004, Büyüksalih et al, 2006).

Topographic maps should have a geometric accuracy of approximately 0.25mm in the map. That means with 1m GSD, corresponding also to a standard deviation of the object coordinates of 1m, a map scale 1 : 4000 should be possible. This is a quite larger scale like justified by the information contents (Topan et al, 2004). Large scale maps do show more details like small scale maps, so a higher resolution is required for large scale mapping. Tests showed a required GSD of approximately 0.05 up to 1mm in the map scale. That means, for the production of a map 1 : 10000 a GSD of 0.5m up to 1.0m is required. The range of the GSD is depending upon the image quality, the area and the country depending contents of topographic maps. A build up area in the USA with wide and straight roads and buildings having a larger space within between does not require the same GSD for mapping like a build up area in India with small and curved roads and small buildings without space within between. (Jacobsen 2002). The very high resolution space images usually do have a very good image quality, so in most cases 0.1mm GSD in the map is sufficient corresponding to a map scale 1 : 10 000 for IKONOS having 1m GSD and up to 1 : 5000 for QuickBird having 0.61m GSD (Passini and Jacobsen, 2004; Topan et al, 2004).

2. NOMINAL AND EFFECTIVE PIXEL SIZE

The GSD must not be identical to the projected pixel size to the ground. OrbView-3 is using staggered CCD-lines – two CCD-lines shifted in the line direction by 0.5 pixels (figure 1). The pixel size projected to the ground for nadir view is 2m, but neighboured pixels are overlapping 50% in both directions like shown in figure 1 below, left. This leads to a ground sampling distance of 1m. But the 1m GSD for over-sampled pixels is not the same like 1m projected pixel size without over-sampling, leading also to 1m GSD.
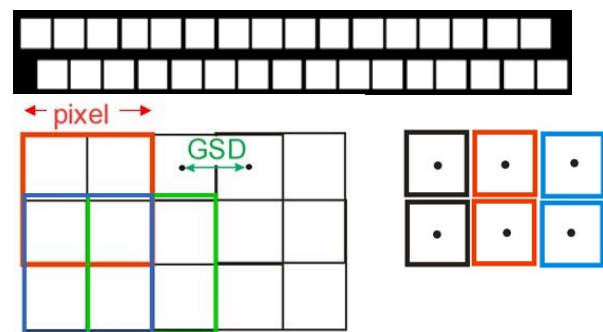

Fig. 1: above: staggered CCD-lines
below: over-sampled   and under-sampled pixels

OrbView-3 is not equipped with a time delay and integration (TDI) sensor which can integrate the reflected object energy by shifting the generated charge in a CCD element with the speed of the forward motion to the next CCD element. By such electronic forward motion compensation a longer imaging time can be reached. Without a TDI, the image motion has to be slowed down by a permanent change of the view direction to achieve a sufficient image quality. OrbView-3 is taking 2500 lines/second for the combination of 2 staggered CCD-lines, so for the satellite footprint speed of 7.1km/sec, the slow down factor is 1.4 (used distance for imaging in the orbit in relation to the distance in the orbit required for imaging with unchanged view direction against the orbit – factor b/a in figure 2).
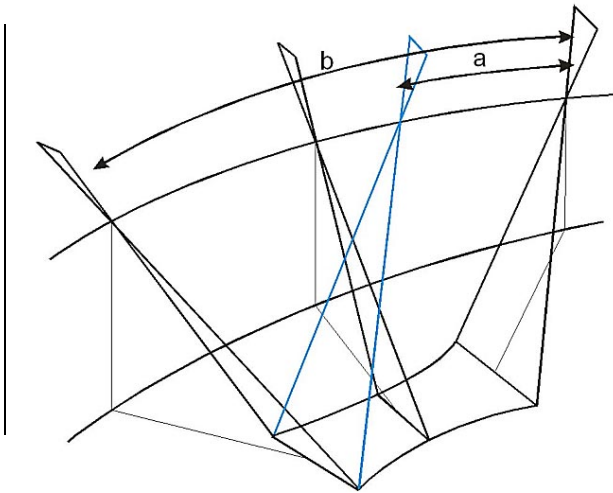
Fig. 2: slow down imaging by permanent change of the view direction

The effective GSD can be determined by edge analysis. A sharp edge in the object space (sudden change of the grey values which may happen at buildings – see figure 4, edge identified between 2 marked points) is shown in the image with a smoother grey value change. The spread out of the grey value change is a function of the imaging quality. A differentiation of the grey value profile leads to the point spread function, showing the effective image resolution. The edge analysis was leading to an effective resolution of 1.0 GSD. By theory it should be in the range of 1.2, but it can be manipulated by an edge or contrast enhancement.

3. VISUAL ANALYSIS

The real information contents have to be checked manually. Of course special imaging conditions like caused by atmosphere and sun elevation may have an influence, but it shows the approximate relation between the possible map scale and the available image. From the area of Zonguldak, Turkey an OrbView-3 stereo pair has been investigated. The GSD in the average is 1.07m.

The OrbView-3 image is using approximately the same range of the grey values like IKONOS. The histograms are not identical because of quite different covered areas.
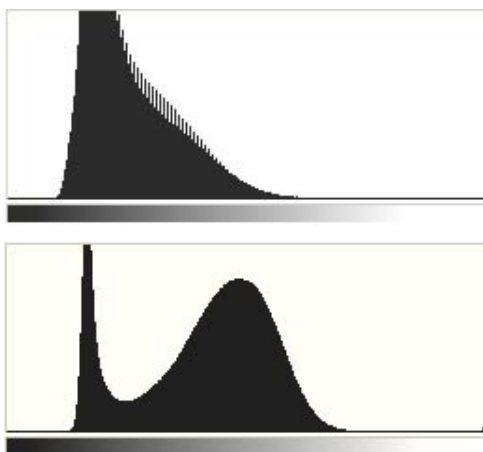

Fig. 3: histogram of IKONOS (above), OrbView-3 (below)

Fig. 4: left: OrbView-3   right: IKONOS

A comparison of image details of OrbView-3 and IKONOS in figure 4 shows no clear differences between both. The edge used for edge analysis (between point 7 and 8 in figure 4) has a very similar structure. In the IKONOS-image more details can be identified, but this may be caused also by different sun elevation. The roof shown in the lower part of the IKONOS-images shows a blooming effect – an enlargement of very bright parts.

A comparison of the OrvView-3 with a SPOT 5 image having quite different GSD (figure 5) shows the meaning of a better image resolution. In the SPOT 5 image only the large structures can be identified, while OrbView-3 allows the mapping of details.
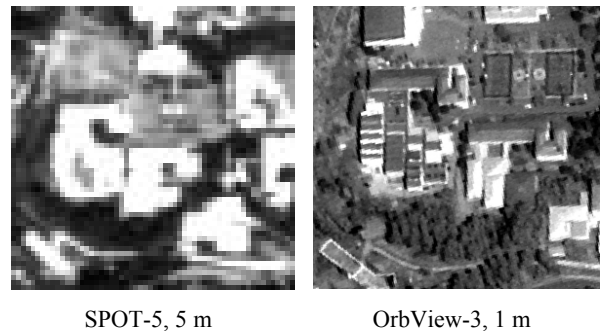

SPOT-5, 5 m   OrbView-3, 1 m

Fig. 5: Buildings in the panchromatic images with different geometric resolution

Also the radiometric resolution is important - OrbView-3 like IKONOS and QuickBird nominally have a radiometric resolution of 11 bit (2048 different grey values), but the used range of grey values is not going over the whole range, so under operational conditions a qualified change from 11bit to 8bit grey values does not lead to a remarkable loss of information. Only in some critical areas differences between the original 11bit and 8bit grey values can be seen like shown in figure 6. On the bright roof more details are available in the original 11bit image. This may be important for automatic image matching; for mapping purposes it is unimportant because in both cases the building can be identified with the required details.
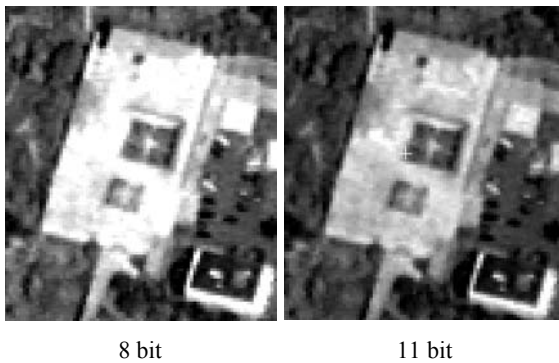
8 bit   11 bit

Fig. 6: OrbView-3 images with different radiometric
resolution

The imaging conditions may be quite different. Haze, clouds
or smoke can reduce the contrast. It is only possible to
enhance the contrast, but this will not lead to the same image
quality which can be reached under optimal conditions. The
sun elevation and also azimuth are important as it can be seen
in figure 7. If the streets are in shadows, object identification
errors may be possible. The used OrbView-3 images have
been taken with a sun elevation angle of 63°, so the shadows
are not so long like in the IKONOS image having a sun
elevation angle of 41° (figure 7). The narrow roads, high
buildings and terrain slope to the North are causing problems
in the Zonguldak area. But sometimes shadows may also
support the object identification. For example a helicopter
landing place on the first view was looking like a roof, but
the missing shadow indicated that it was located in the same
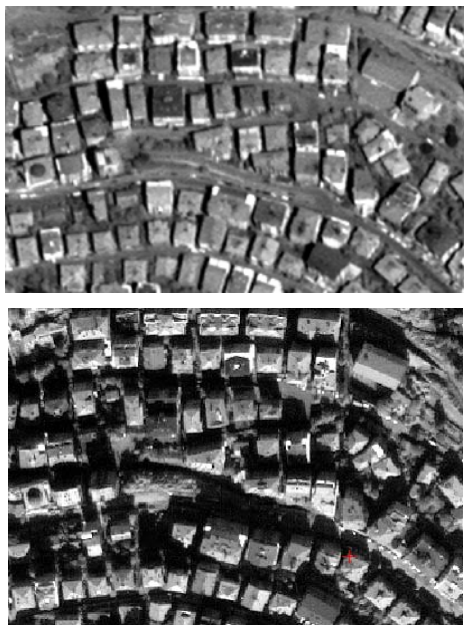elevation like the surrounding grass land.

Fig. 7: OrbView-3 with 63° (above), IKONOS with 41°
sun elevation (below)

Figure 8 demonstrates the influence of the third dimension.
The imaged tent looks different in both images of the stereo
combination, requiring some knowledge for the object
interpretation.

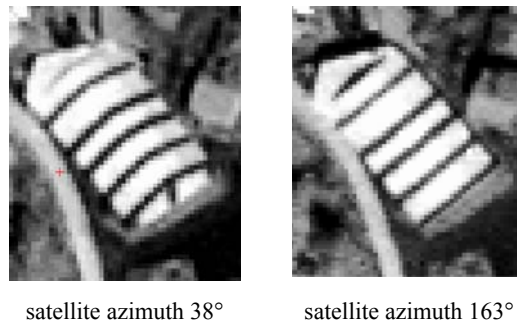satellite azimuth 38°   satellite azimuth 163°

Fig. 8: Imaging of a tent from different directions, in both
cases satellite elevation = 72°

The image interpretation is dominated by the contrast, but the
object identification is quite different for different objects.
Planned areas with larger, well arranged buildings can be
mapped easier like unplanned areas with smaller and not
regular objects. In addition the unplanned areas in Zonguldak
are located in the slope parts, looking quite different from
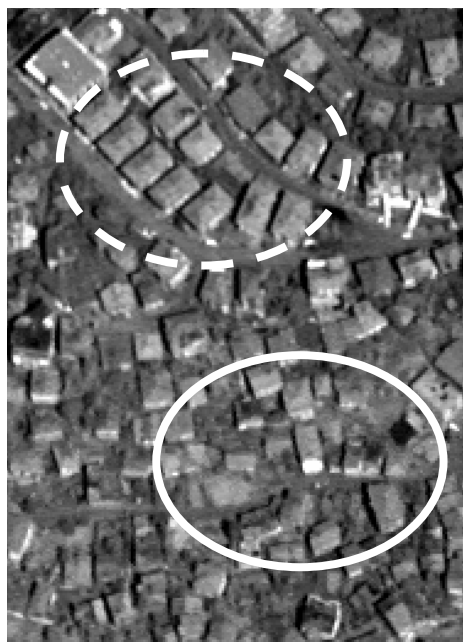different direction (figure 9).

Fig. 9: Planned (dashed ellipse) and unplanned (solid
ellipse) areas shown in an OrbView-3 image

Not every building has a rectangular shape. Especially in the stronger inclined parts, the building sides may not be parallel. Figure 10 shows a not regular building (a), a rectangular building (c) and a not so high building not clearly marked by shadows (b). The building (b) at first has not been identified, mainly because of the missing contrast enhancement by shadow.
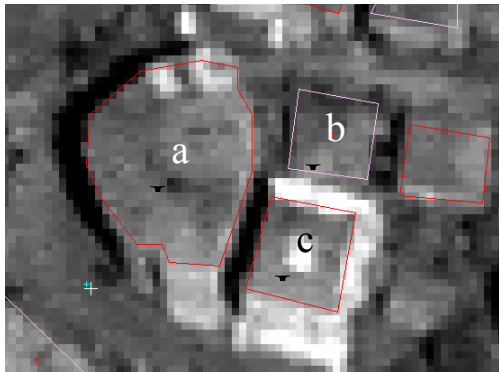

Fig. 10: not regular (a), unrecognized (b) and usual (c) building shapes - OrbView-3 image

Multispectral space images do have a lower geometric resolution like panchromatic images generated by the same sensor. But the color is supporting the object interpretation. Pan-sharpened IKONOS images based on red, green and blue (RGB) do have the same geometric resolution of the panchromatic images but also the advantage of the color (figures 11 and 12). OrbView-3 cannot take panchromatic and color images at the same time like IKONOS and QuickBird, so no direct pan-sharpening was possible.
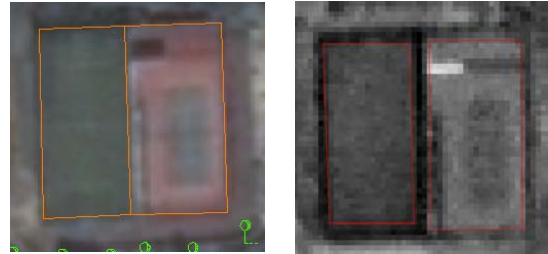

OrbView-3 panchromatic
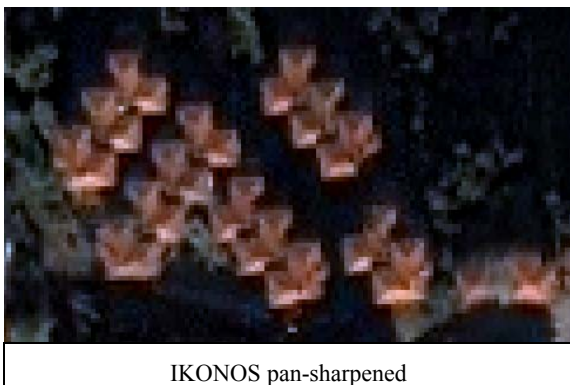
IKONOS pan-sharpened

Fig. 11: Additional information by color in the images with same geometric resolution

The color information supports the classification of land use type. Figure 12 shows two sport places with grass and concrete in pan-sharpened and panchromatic images. The advantage of color is obvious. Because of not parallel data acquisition of color and panchromatic, this advantages usually does not exist for OrbView-3.

IKONOS pan-sharpened   OrbView-3 panchromatic

Fig. 12 Same objects shown pan-sharpened and panchromatic

Figure 15 shows the mapping result based on OrbView-3 panchromatic in relation to IKONOS panchromatic and also pan-sharpened images. Of course the pan-sharpened image has some advantage for the object identification, but a comparison with mapping the same IKONOS image in panchromatic showed only limited advantages of the color. Especially in areas with lower contrast few more objects can be identified with the support of the color, but the advantage is limited. The main difference between mapping with panchromatic OrbView-3 and pan-sharpened IKONOS is still based on the slightly better image quality of IKONOS.
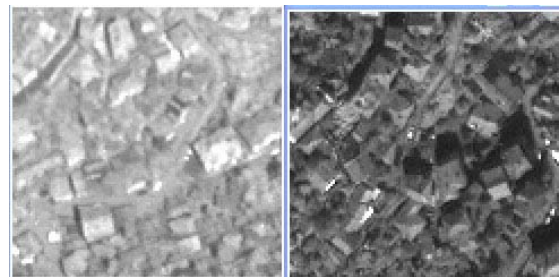

Fig. 13: unplanned build up area in OrbView-3 (left) and IKONOS panchromatic (right)

Fig. 14: planned build up area in OrbView-3 (left) and IKONOS panchromatic (right)

Figure 13 demonstrates the differences between OrbView-3 and IKONOS panchromatic in difficult unplanned areas where several buildings have been marked as only detectable,

but could not be vectorized in the OrbView-3 image, but have been mapped in the IKONOS image. In the planned build up areas (figure 14) there is no obvious difference in the identification of the objects – only an influence of the different sun elevation can be seen. The quality difference of both images is limited, but available. This may be caused by the over-sampling of the OrbView-3 image having 2m size of the projected pixel, but only 1m GSD.

The mapping result of a sub-area is given in figure 15. Small differences in mapping are available for the smaller buildings in the lower centre part. Apart from the differences caused by time delay between the images as 2002 for IKONOS and 2005 for OrbView-3, IKONOS has more vectorized details than OrbView-3. Especially all buildings and roads (wide or path) can be recognized in the IKONOS image. Some roads can not be vectorized caused by the shadow effect in the pan-sharpened IKONOS image. A summary of object identification is given in table 1. There are still some obvious differences for mapping with OrbView-3 and IKONOS pan-sharpened images. But nevertheless, the differences are limited to smaller objects and this does not mean, that OrbView-3 images are not usable for the generation of topographic maps in the scale 1 : 10000.

Mapping results based on OrbView-3 panchromatic image buildings which could be identified but not vectorized are shown as cross
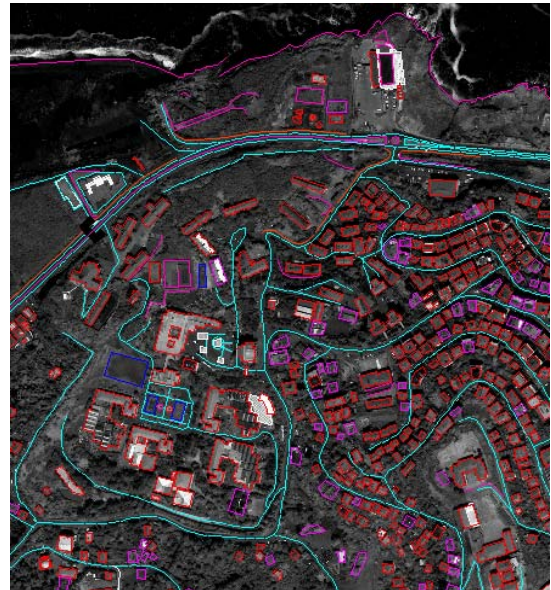
Mapping results based on IKONOS panchromatic image
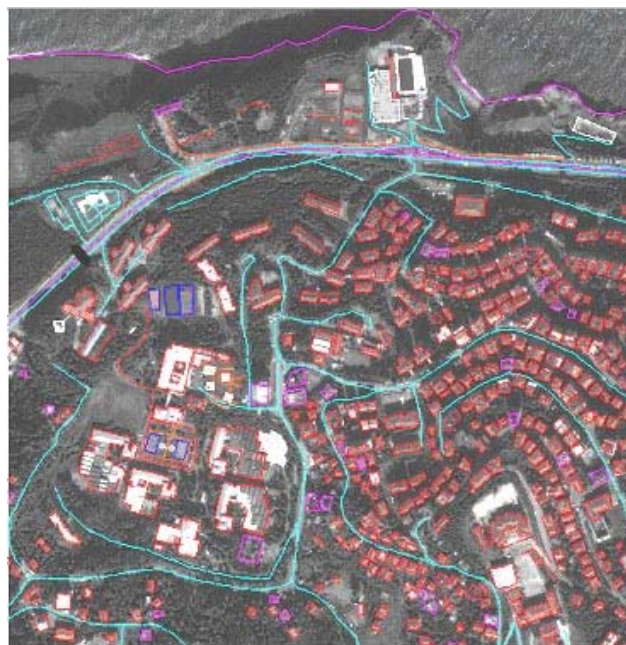
Mapping results based on pan-sharpened IKONOS image

Fig. 15: Mapping results based on panchromatic OrbView-3 and panchromatic and pan-sharpened IKONOS images

Object	Image	detection			recognizing		
		***	**	*	***	**	*
Large individual buildings	OV	√			√		
	IKO	√			√		
Small individual buildings	OV	√				√	
	IKO	√			√		
Wide roads	OV	√			√		
	IKO	√			√		
Small roads	OV	√				√	
	IKO	√			√		
Sport yards	OV		√			√	
	IKO	√			√		
Cemetery area	OV		√			√	
	IKO	√			√		
Coast line	OV	√			√		
	IKO	√			√		
sideline of roads	OV		√			√	
	IKO	√			√		
Wall	OV		√				√
	IKO		√			√	
Sidewalk	OV		√			√	
	IKO	√			√		
Footpath	OV		√				√
	IKO		√			√	
Pool	OV			√			√
	IKO	√			√		
Grass land	OV		√			√	
	IKO	√			√		

Table 1 Summary of detection and recognition using OrbView-3 panchromatic and IKONOS pan-sharpened images

*** = without problems,

**=medium,

*= difficult identification

4. CONCLUSION

The very high resolution space images with 1m GSD can be used for the generation of topographic maps with the scale 1:10000. No problem exists with the geometric mapping accuracy; the difference and limitation of mapping is based on the information contents of the space images. Because of the special image generation with over-sampled pixels, the OrbView-3 images do have a quality slightly below IKONOS panchromatic scenes. IKONOS has the advantage of parallel acquisition of panchromatic and color allowing the generation of pan-sharpened images having some advantages for the object identification. But nevertheless OrbView-3 and IKONOS scenes can be used for the generation of topographic maps 1 : 10 000. The mapping for 1 : 5000 should not be done with OrbView-3 images, but also IKONOS images do have some limitations for such a large scale. The direct use of the original 11 bit scenes has not a remarkable influence for the object identification, allowing a qualified reduction of the original 11bit grey values to 8bit.

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6. ACKNOWLEDGEMENTS