

# SEMANTIC ANALYSIS OF SPACE IMAGERY FOR MAPPING PURPOSES

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*Abstract* - From the area around Zonguldak several space images with different ground sampling distance (GSD) from 30m down to 62cm are available. The semantic information of Landsat images is too poor for the generation of topographic maps, while QuickBird images do allow a mapping in the scale 1 : 5000. Not only the GSD is determining the possible map scale, also the spectral and radiometric resolution is important. The imaging conditions, especially the sun elevation with the corresponding length of shadows, do lead to quite different results especially in cities with narrow streets. The possibilities and limitations of mapping with the different space images, partially with the same image type taken in different month, has been analysed.

## I. INTRODUCTION

Under usual conditions the geometric quality of space images guarantees a sufficient mapping accuracy – the geometry is not a real problem. The limitation of the map scale which can be generated based on space imagery is caused by the image information contents. Images with a high resolution do show details which may be required only for a large map scale, while the details visible with medium resolution may be sufficient for a smaller map scale.

In a GIS the positions are available with their national coordinates, so by simple theory a GIS is independent upon the map scale, but the information contents corresponds to a publishing scale – for a large scale more details are required, for a small scale the generalisation is stronger. In no case the full information is available in a GIS; for a large presentation scale the generalisation starts with the size of building extensions which are included, while for small scales the full effect of generalisation is required - this includes comprehension, selection and reduction, simplification of type, change to symbols and classification with underlining and shift. So for large presentation scales more details have to be identified in the images while for smaller scales a larger GSD may be sufficient.

As a rule of thumb, a ground sampling distance (GSD) of 0.05mm up to 0.1mm in the map scale is required for a sufficient map contents. That means for the generation of a map 1:20 000 a GSD of 1m up to 2m is necessary. If the GSD exceeds 5m, the visibility of all required elements is not guaranteed because some objects have to be shown in any case even if they are small. This rule can be used for a satisfying image quality. Not in any case this is given. Caused by long shadows, an insufficient radiometric resolution or other effects the image quality may be limited. On the other hand colour may improve the identification of objects. By this reason the different space images have to be checked individually.

## II. GROUND SAMPLING DISTANCE

The GSD is the distance of the centres of neighbored ground pixels. Because of over- or under-sampling it is not identical to the size of the projected pixel. So for example the staggered CCD-lines (figure 1) of SPOT5 may be used in the case of super mode for the generation of 2.5m GSD while the physical pixel size on the ground is 5m. For the user, the GSD is presented as the pixel size on the ground. Over- or under-sampling are only changing the contrast which may be caused also by the atmosphere.

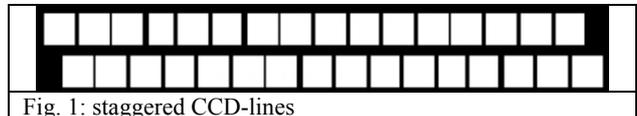


Fig. 1: staggered CCD-lines

The effective resolution must not correspond to the nominal GSD. This can be analysed by an edge analysis. A sharp change of the grey values on the ground (different reflection of the sun light) will be reduced to a more soft change of the grey values in the image. The length of the grey value ramp is an indicator for the effective resolution. The differentiation of the grey value profile leads to the point spread function showing directly the effective GSD.

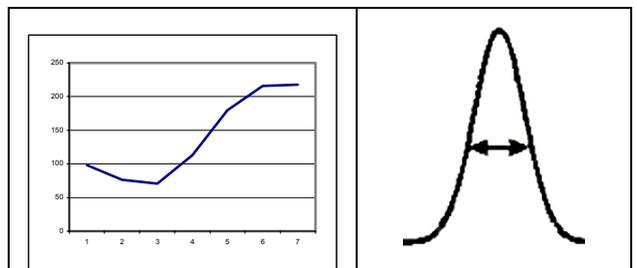


Fig. 2: grey value profile of an edge in the image – SPOT 5, Zonguldak

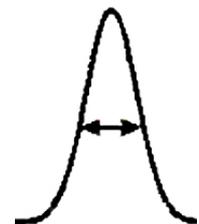


Fig. 3: differentiation of grey value profile → point spread function

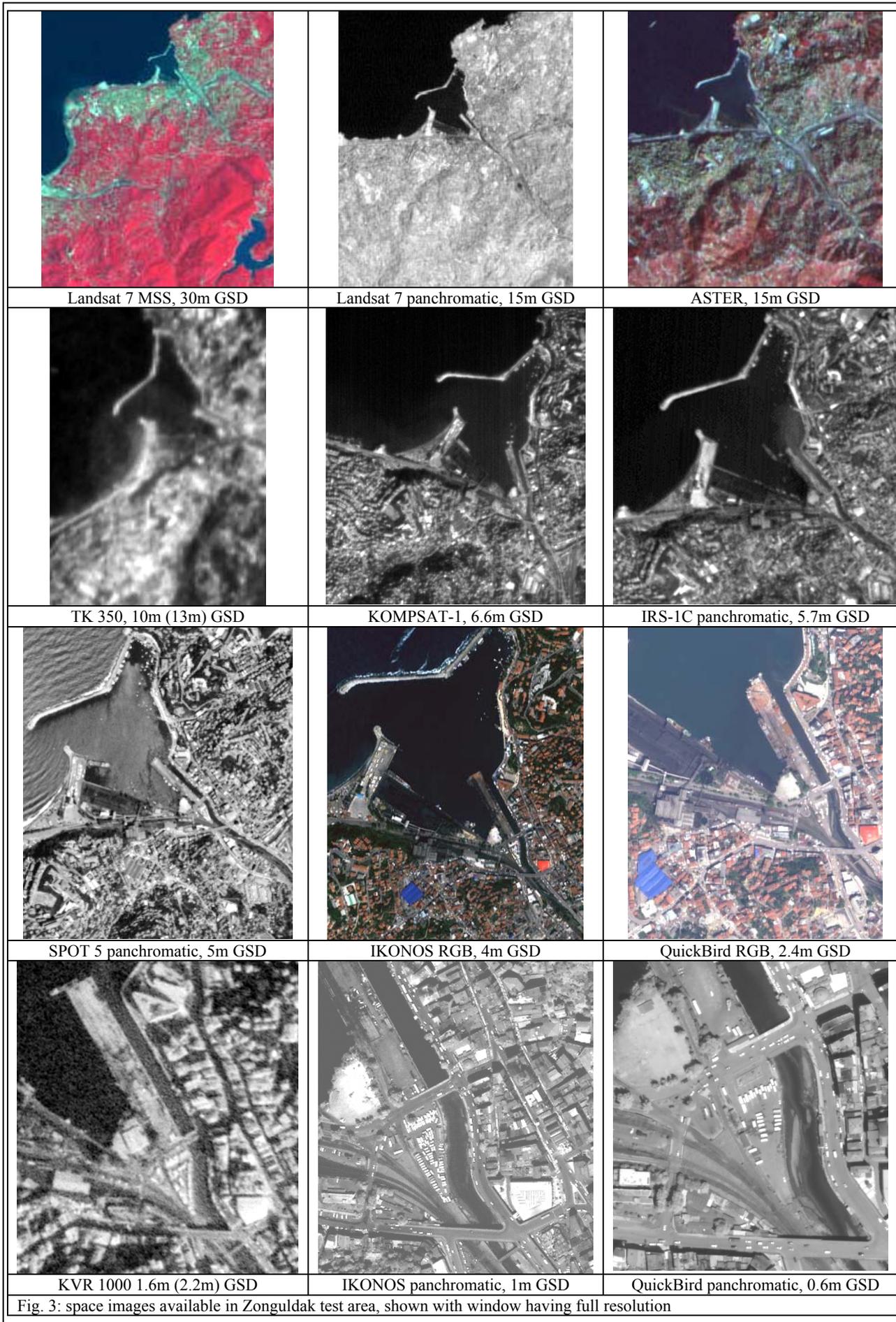


Fig. 3: space images available in Zonguldak test area, shown with window having full resolution

The grey value profile of an edge in the image shown in figure 2 is typical. Most space images are improved by contrast enhancement, leading to reduced grey values in front of the edge in the image. The example of figure 2 is resulting in a factor for the effective GSD of 1.16, but as average of 6 edges it is 1.03, so the effective GSD of the SPOT 5 image was identical to the nominal GSD. All used images have been analysed for the resolution. The photographic images from TK350 and KVR1000 are available with a GSD of 10m and 1.6m. In both cases it was a too optimistic value. The effective GSD has been determined for the TK350 with 13m and for the KVR1000 with 2.2m. For the IRS-1C a multiplication factor of 1.2 (effective GSD = 6.9m instead of 5.7m) and for the EROS A a factor of 1.3 (effective GSD = 2.4m instead of 1.8m) has been seen. The lower effective resolution of the IRS-1C in relation to KOMPSAT-1 having a larger nominal GSD of 6.6m is obvious in figure 3. For all other digital space images the effective GSD was identical to the nominal GSD. Of course the reduced resolution may be caused by actual atmospheric conditions, so with a limited number of images no general results can be achieved.

### III. COMPARISON OF IMAGES

Windows of the images used in the Zonguldak test area can be seen in figure 3. The dependency of the information contents upon the GSD is obvious – in the QuickBird image building details can be seen while in the Landsat image only the structure of the settlement can be classified. Landsat and ASTER are shown as false colour images (green, red, near infrared shown as blue, green and red). Caused by the strong reflection of active vegetation in the near infrared spectral range shown in red, a good separation between build up and rural area is possible. In the ASTER image with 15m GSD always some structures in the city and the major roads can be identified. This is not possible in the panchromatic Landsat image having the same GSD – the quality of panchromatic Landsat is not satisfying, even with single bands ASTER shows more details. The TK350 photo was digitized corresponding to 10m GSD, the nominal resolution named by Sojuzkarta. Not only the edge analysis, also a simple comparison with ASTER and panchromatic Landsat indicates that TK350 does not have the information contents corresponding to 10m GSD, it is not better like panchromatic Landsat. In addition the original photo includes a high number of scratches and visible film grain which had to be filtered.

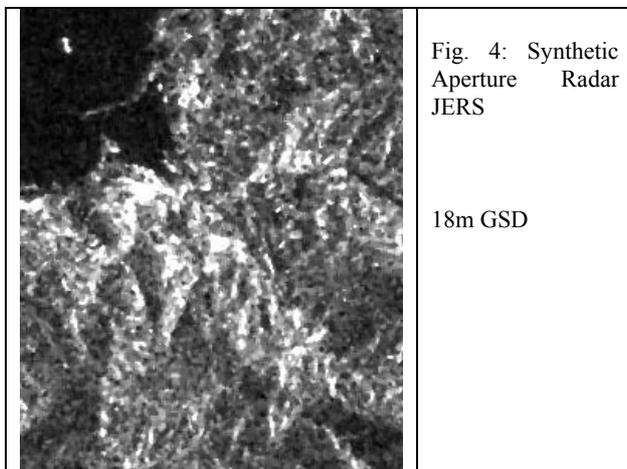


Fig. 4: Synthetic Aperture Radar JERS

18m GSD

A comparison of Landsat and ASTER with the JERS synthetic aperture radar (SAR) image having a similar GSD demonstrates the lower information contents of SAR in relation to optical images. SAR is disturbed by speckle and especially in build up areas individual strong reflections occur by buildings acting as corner reflectors. A comparison within a EuroSDR test (Lohmann et al 2004) of aerial SAR and optical images having the same GSD resulted in information contents of the SAR images in relation to the optical images in the range of 60% to 100%.

Starting with 6.6m GSD of the KOMPSAT-1 it is becoming important for mapping purposes. The road structures also within the cities are clear, but it is not possible to identify individual buildings. Only large ones and industrial complexes or building blocks can be mapped. This is sufficient for maps 1 : 50 000.

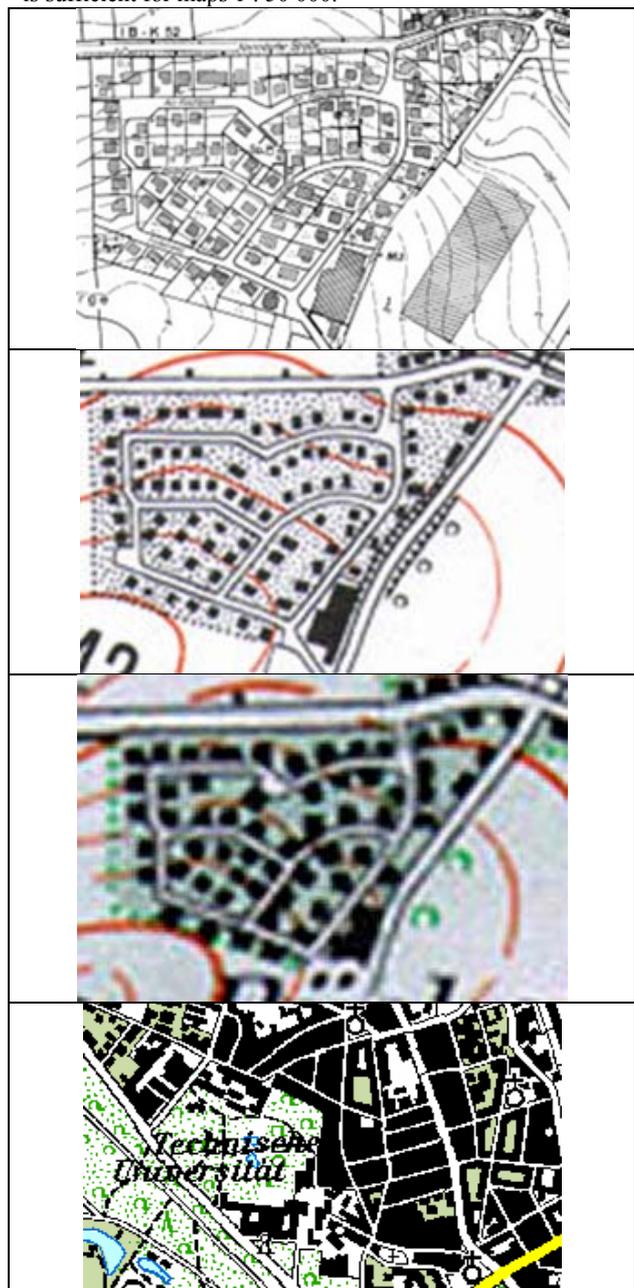


Fig. 5: contents of a German topographic map 1 : 5 000, 1 : 25 000, 1 : 50 000 and 1 : 50 000 in city

The dependency of the information contents of topographic maps upon the scale can be seen in the examples in figure 5. In the scale 1:5000 details of the buildings including extensions are shown. In 1 : 25 000 in open build up areas the individual buildings are available, but mainly as symbol, while in 1:50000 the buildings are only plotted as symbols. The number of buildings has been reduced, so only the structure of the settlement can be seen. In densely build up areas only very large buildings and building blocks are presented. Corresponding to this, a GSD in the range of 5m is sufficient for the generation of maps 1 : 50 000.

A comparison of the panchromatic images of KOMPSAT-1, IRS-1C and SPOT 5 results in clear differences of the information contents. Even with the smaller nominal GSD of 5.7m IRS-1C does not contain the same details like KOMPSAT-1 with 6.6m GSD, but this resulted also in the edge analysis leading to a nominal GSD of 6.9m for IRS-1C. SPOT 5 with 5m GSD shows more details and has a very good contrast. It is not far away from the identification of the individual buildings.

The original colour image of IKONOS with 4m GSD shows the individual buildings because of the dominating red roofs in the city of Zonguldak, but the buildings are too small for individual mapping. In general the manual classification of the different objects is supported by the colour and the mapping is easier like with panchromatic images. The mayor roads can be identified in IKONOS colour images.

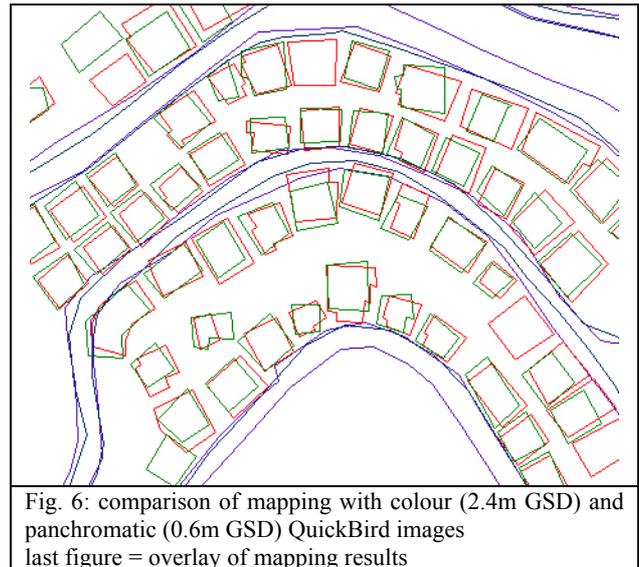
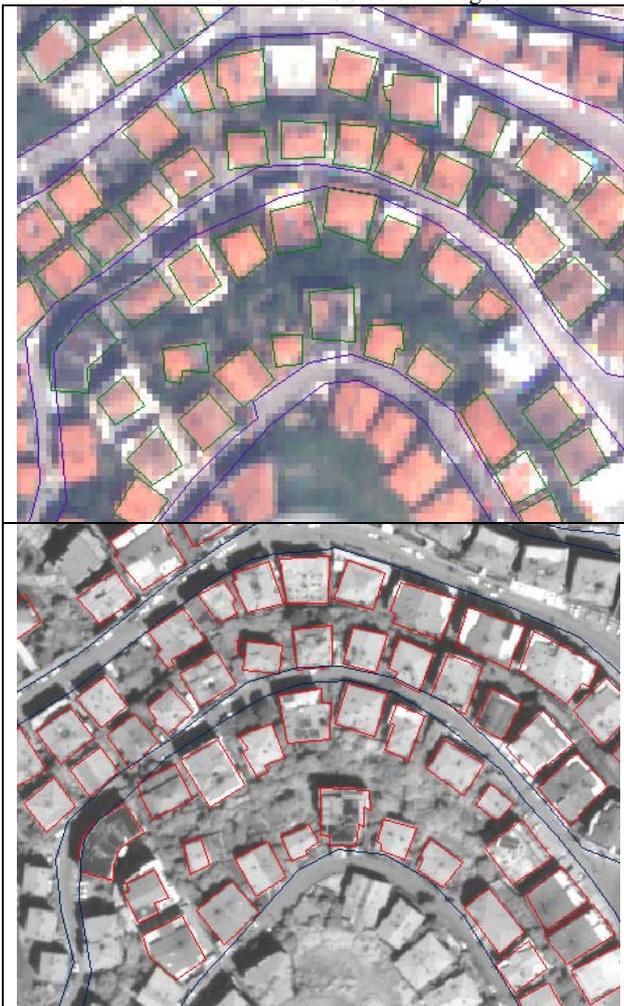


Fig. 6: comparison of mapping with colour (2.4m GSD) and panchromatic (0.6m GSD) QuickBird images  
last figure = overlay of mapping results

With a ground sampling distance of 2.4m it is difficult to map the correct shape of the buildings which are not in any case right-angled and having the front parallel to the street. With 60cm GSD it is not a problem to map the building details. Caused by object, the mapping of the street lines is not so simple even in the panchromatic QuickBird image. Partially curb stones exists, partially not and partially parking areas are going without clear limits up to the buildings. Also with high resolution aerial images this would not be easier. Under this condition there is a sufficient fit of the street lines. The contents of the map based on the 0.6m GSD corresponds to a map scale 1:5000. Also the required accuracy of 0.25mm in the map corresponding to 1.25m is not a problem; it is only limited by the definition of the objects.

The mapping of the buildings is based on the location of the visible roofs. Ortho images usually are generated with DEMs describing the bare ground, so the roofs are displaced by the building height multiplied with the tangent of the incidence angle. For example the roof of a 10m high building is displaced 1.7m for an incidence angle of 10°. This is not far away from the required mapping accuracy, but it may disturb the relation buildings to street lines. For an incidence angle of 30° always 5.1m displacement occurs, so it is important to take care for a not too high incidence angle.

Three IKONOS images are available taken at different days of the year leading to sun elevations of 67.2°, 41.5° and 45.5° causing a length of shadows for a 10m high building of 4.2m, 11.3m and 9.8m. The distance between the buildings rows at the streets are in the range of 10m to 15m, the backyards are partially smaller. The area shown in figures 6 and 7 has an inclination of 10° up to 15° to the north direction enlarging the length of shadows even at levelled streets where the buildings on the hillside are elevated against the street. Caused by such conditions, in the second IKONOS image having a sun elevation of 41° partially the streets and also backyards are totally in the shadow. Even a high pass filtering did not improve the visibility of details in the shadows. So with this image it was difficult to map the streets; in some cases it was not easy to identify on which side of the buildings the street was located. Even a pan-sharpening like shown in figure 6 did not improve the situation. It is not a problem to map the individual houses, but this is not sufficient for the identification of streets and the street connections.

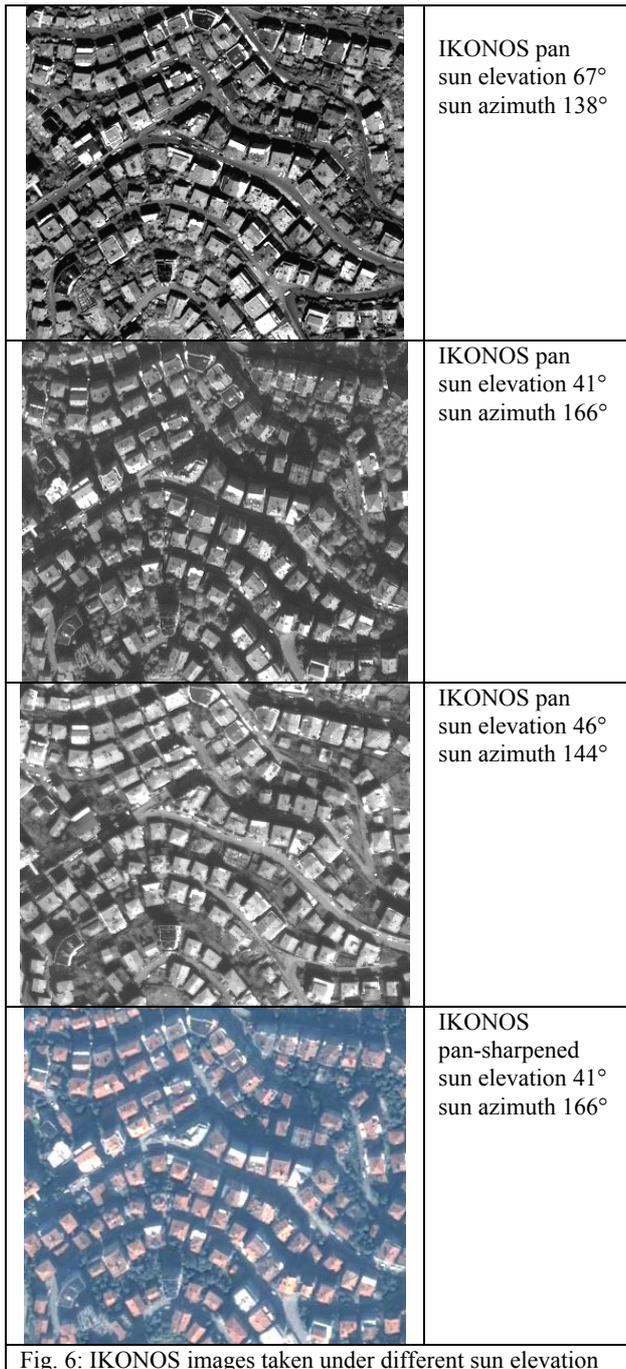


Fig. 6: IKONOS images taken under different sun elevation

Not only the sun elevation is important - the third image has just 46° sun elevation against 41° for the second, also the sun azimuth plays a roll in relation to the street azimuth like visible in the third image in relation to the second. With the third image the mapping of streets was quite more easy.

The same conditions we may have also for the other types of space images. By this reason the rules for the object identification are not totally fixed. We do have an influence of the shadows – also cloud shadows are causing large problems and in some cases the image quality may be influenced by the atmospheric conditions.

#### IV. CONCLUSION

The general rule of the required ground sampling distance of 0.05 up to 0.1mm in the publishing scale has been confirmed, but it can be seen, that this rule is not totally fixed. The effective GSD should be determined by edge detection because in few cases it was not identical to the nominal size.

	required GSD
urban buildings	2m
foot path	2m
minor road network	5m
rail road	5m
fine hydrology	5m
major road network	10m
building blocks	10m

Table 1: required GSD for object identification based on panchromatic images

Based on the tests in the Zonguldak area and some previous ones, the rule for object classification listed in table 1 has been found. Colour images do improve the situation, so in the case of colour the required GSD may be 1.5 times as much. Images having a GSD exceeding 10m are not sufficient for the generation of topographic maps. With a GSD in the range of 5m to 7m not all important objects can be seen if the contrast is not sufficient. The good contrast of SPOT image was leading to quite better results like the IRS-1C. With IKONOS having 1m GSD a mapping in the scale 1:10000 and with QuickBird a mapping in 1:5000 is possible. Now IKONOS images can be ordered also with the original GSD of 0.8m, these images have not been investigated.

#### ACKNOWLEDGMENTS

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