THE NEW APPROACH TO PROCESSING OF HIGH RESOLUTION IMAGE DATA APPLIED TO IMAGE MAPS IN SCALES FROM 1:10 000 TO 1:50 000.

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ABSTRACT

Satellite image maps in different scales and with different accuracy are required by governmental and local authorities in Poland. The new approach to processing of high resolution satellite image data has been developed at the Institute of Geodesy and Cartography in Warsaw, Poland. The excess of unwanted information and the lack of features required in a map was the weak point of the so far produced image maps. The search for better solution resulted in a 'cartographic' approach to image processing that is presented in the paper. The image data is interpreted, selected, important features enhanced, unwanted diminished, and the simplified color palette is used for coloring of the basic categories of topographic objects. The use of colors is thus meaningful not accidental, and distinct colors denote build-up areas, forests and waters. Examples illustrate the evolution of the approach starting from 1994. Russian space photographs KVA-1000 and KWR-1000 have been used for elaboration of digital image maps in the scales 1:10 000, 1:25 000 and 1:50 000 for regional and town planning. The mosaic of 29 aerial photographs that simulate new high resolution satellite image of IKONOS has been used for elaboration of Slowinski National Park map in scale 1:25 000 for tourism and monitoring purposes.

1 INTRODUCTION

Twenty-six years after the first satellite image map of the Lake Tahoe area, USA, has been produced satellite images have little impact on civilian mapping [Dixon-Gough, 1995]. Hopes for "production of maps untouched by human hands" did not come true [Zarzycki, 1992]. After several years of exercising with satellite image the split between remote sensing specialists and cartographers strengthened as cartographers come to conviction that satellite image is not good enough for topographic mapping. Satellite image map started its independent life similarly as it happened to photographic map based on aerial photography 50 years earlier. Living separate lives the traditional cartographers' map, the orthophoto map and satellite image map have unfortunately little mutual influence. In case of satellite image map no distinctive graphic convention has yet been decided which results in a variety of designs. Satellite image map is still not easily recognized and it is often even not considered a map [Forrest, 1999]. It is not available in shops and tourists or drivers do not use it. Outside the scientific community the satellite image map is rarely used in more respectful role than as a poster or a TV weather report map. Paradoxically the artificial representation of the Earth's surface is shaping geographical imagination even today when the true image of the Earth is available.

2 SATELLITE IMAGE MAP TODAY

There is no wonder that satellite image maps are not in common use and do not yet play a significant role in civilian mapping as it was hoped. Three reasons seem the most important:

- available satellite images were not good enough,
- the characteristics of optical images of the Earth was not thought out well enough,
- the design of satellite image map was often accidental and made without sufficient care.

Scales of topographic maps that are meaningful for development of a country are 1:100 000 and larger. To meet the requirements of such maps the satellite image should not only be accurate enough in geometrical sense but also should permit consistent identification of the features of which the map content consists. Besides forests and lakes easily classified by the computer there are such features as road networks, hydrology, urban and rural buildings, railways and these are not easy to trace in the image. Satellite images available till now, including Landsat TM, SPOT, KFA-1000 and IRS 1-C, are not reliable for topographic mapping in scales larger than 1:100 000, and this is because of the 'content' requirement [Wright, 1999]. The satellite images available now are of medium and low spatial resolution [Fritz, 1998]:

very high < 0.5 m   0.5 < high < 3 m   3 < medium < 30 m   30 < low < 300 m   300 < very low

According to this classification there is no difference between Landsat TM (30 m) and IRS 1-C (6 m) and this agrees with previous observation: some classes of features like buildings, narrow roads and rivers are only visible in images with spatial resolution of 1-2 m.

From a graphic point of view one pixel of the original satellite image should never exceed 0.1mm when printed on paper, to keep the image continuous, sharp and look technically perfect. This means that Landsat TM images look good in scale 1:300 000 and SPOT panchromatic images in scale 1:100 000.

The nature of the image of the Earth's surface acquired from a distant point above is such that it is acquired in the presence of the atmosphere that disperse light especially the blue band, and is less transparent for the high spatial frequency band of the image than for the low. In result the true color image is the less colorful and the less sharp in details the more distant is the point of observation.

The natural role of colors in the image is quite opposite to that in the map. Different objects (lake, meadow) appear similar and the same time one class of objects (buildings) has variety of colors. The image with its fixed spatial resolution does not depict many important topographic features because they are too small or have too low contrast. Also it can not show these features (roads, streams, buildings) which are hidden under the trees.

The design of the satellite image map evolved from false color composite with red vegetation to natural color composite with black hydrography. Such colors interesting for scientists are confusing for cartographers and many common users. Another strange distinct feature of satellite image map was very often unsharp image resampled from the original with the use of cubic convolution to fit the geometry of the larger scale. The last weak point of the satellite image map design is the insertion of linear features such as roads, borders and contours into the image. Precise sharp graphics derived from vector data base does not stick to the background of delicate, a little hazy image and stand out rather than integrate.

3 NEW ROLE OF THE SATELLITE IMAGE MAP

With the advent of IKONOS satellite operating since the end of 1999 [ikonos, 2000] everything begins anew for the satellite image map. Its current role is likely to change drastically as the spatial resolution of new images (1m panchromatic, 4m blue, green, red, IR) is suitable for topographic mapping in the range of scales (1:10 000 - 1:50 000) meaningful for the economy of countries. Unlike in 1970's the potential editors of image maps are equipped with powerful computers, software and gigabyte storage capacities essential for image processing. What is missing is the improved design of satellite image map in anticipation of its new role in topographic mapping.

This new role is connected with the changing role of the traditional map. With the development of geographic information systems digital maps took over the main function of a topographic map: the accurate depiction of all features to enable reliable measurements. Remaining no less important function is the clear, pleasant and imaginative portrayal of the terrain so that to develop an understanding of the geography of the area [Zarzycki, 1992]. The new, reduced in function traditional topographic map can in most cases share the area of applications with future satellite image map as being the best devices for understanding the terrain geography not limited in size by the window of a computer. In this new role of the displayed or printed paper map the most helpful tool seems to be the map design as the interactions of basic design elements within the map determine the impact of its effectiveness for communicating a cartographic message [Trainor, 1999].

Having noticed the weak points of satellite image map it is worth considering how to increase the role of map design in satellite image map creation. Passive approach to the image data processing preserves natural, objective but also chaotic way in which the Earth surface is presented in the image. The advantage of traditionally designed map is clarity and ease in perception in places where the image is a puzzle.

Attempts to imitate the cartographer's attitude and to change the image appearance to look more like a map are not new. In 1965 Merriam enhanced the texture of the aerial photography and reduced its tones to a uniform gray by photomasking [Merriam, 1965]. In image maps edited today the black hydrography is often colored with more pleasant blue 'artificially' as the blue is impossible to achieve from a given set of data. For the same reason there are roads, borders and place names inserted to the image. In future it will be difficult to avoid more cartography in satellite image maps. The question is only how to adopt some ideas of cartographic generalization and translate them into satellite image environment. The development of such cartographic approach might only improve its graphic form and confirm its important role in future topographic mapping.

Centering attention upon imperfections of the space image and the image map one can not overlook the advantages that outweigh. They are the grounds for dynamic development of mapping from space we observe today. There are advantages over the traditional map either. Playing the role of the base map the satellite image map is faster and cheaper in edition. By depicting temporary state of geographic phenomena enables monitoring of natural resources especially national parks and reserves. By showing details missed in the traditional map the image map is more realistic and more imaginative. These advantages even in scales available before IKONOS have been noticed and exploited [Galvis, 1995], [Khorsandian, 1997].

4 A CARTOGRAPHIC APPROACH

4.1 Image perfection

From a cartographic point of view it is of vital importance to ensure correct technical quality of the image used in the map. Spatial resolution of the image should be harmonized with the assumed scale of the map and it is reasonable to hold the criterion: 0.1mm = spatial resolution x scale. This preserves the image from blur and noticeable pixel structure. According to this criterion selected scales and corresponding spatial resolutions are listed in table 1.

scale	spatial resolution
1:100 000	10m
1:50 000	5m
1:25 000	2.5m
1:10 000	1m

Table 1. Scales and the corresponding spatial resolutions following from the criterion of 0.1mm.

Because of unfavorable influence of the atmosphere during image registration some losses in spectral and spatial domain of the image are unavoidable. To improve the image quality in attempt to restore its presumable look as if there was no light diffusion the high pass filtering is useful. By combination of high pass filtering and unsharp masking, once tedious job with the use of analogue methods now easy with Adobe Photoshop software , one can reduce high tonal contrast and enhance high frequency band of the image. With the increase of contrast in small areas the sharpness and the visibility of details improve. To enrich colors and attain balance between them one can manipulate with colors in different mode by analyzing the image in composition of intensity, hue, saturation instead of red, green, blue.

All uniform tone, flat areas without any texture are undesirable in the image. There should not be any clouds, white snows or black forests because they do not belong to the nature of the image graphics.

Images mosaicked in a map should not show any traces indicating different light conditions during their acquisition.

All technical imperfections of the image depreciate its credibility reduce the power of transmission of the geographic message. High quality image fulfills a function similarly to that of accurate drawing in the traditional map.

4.2 Map design

The nature of optical images is the objectivity in portrayal of a real scene. This objectivity one might consider a defect if its legibility and that of a traditional map are compared. The necessity to trace courses of roads and rivers, to puzzle and guess what does particular feature mean in the image may be tedious especially as secondary importance feature, for example a balk is much more distinct. Typical informational chaos in the image is slightly reduced by natural colors that are often misleading. In comparison to the map one is missing the hierarchy and order that makes the perception easier. But the map is far from being an objective image of the reality. It is rather some idealistically arranged view and it is this arrangement that makes the map legible and an understanding of the geography of the area faster.

Discovering rules of map design one may notice that it deals with graphic presentation of the information contained in the map. Although the content of the space image resembles that of a topographic map, it is in the map divided into categories of similar objects, e.g. waters, woods, buildings. As the function of map design is to communicate this information effectively to the user, all categories are visually distinguished with the use of available means: colors, lines, signs. It is not acceptable in the map that waters or buildings are presented in different colors as it happens in the image.

It is not easy to imitate this cartographic rule processing the space image. First one must get the technical possibility of visual distinction of some category of objects. If we have for example the locations of all waters within the image as a black-white mask, meaning a bitmap geometrically coordinated with the main image, we would be able to manipulate colors in the image at places marked by the mask. To make such a mask one must trace all waters within the image by hand, at least as long as no suitable software is available. In the process of tracing masks for all the categories we want to distinguish the automated classification is helpful though it is unsatisfactory in case of narrow rivers or buildings. Sometimes the job has been already done and there exists adequate data in the geographic data base. They only need to be converted from vectors to black-white raster masks.

The possibility of color manipulation of a group of objects has two advantages. Firstly it enables to uniform the color of all objects in a group. Secondly it allows to assign to the group such a color that is proper in relation to colors of other groups. The extent of color manipulation should be controlled. This comes easier when the image is composed of intensity, hue, saturation components rather than red, green, blue. To obtain adequate distinction of a group it is enough to uniform and to change the hue component leaving two others unchanged. Sometimes even slight variety of hue in a group is acceptable if visual relation of all objects is preserved.

The main categories of objects expected to be easy perceived in the map are open grounds, waters, build-up areas and woods. The major distinction in the landscape between land and water should be visually clear. This need not be achieved by strong color contrast as these categories are recognized by characteristic shape rather than color. For open waters very pale tint of blue is generally sufficient to bring out the outline of the land surface [Keates, 1973]. Visual reinforcement of the outer edge of the land can be made by application of vignetted band of deeper color bounding the water area. This manner of distinction between two major categories is apparently suitable for space images.

The most important category on the land is build-up area so its contrast to the open ground should be emphasized. This category consists of many usually small objects which rectangular shape and typical arrangement would be sufficient distinctive features if buildings were easy recognized in the image. Unfortunately their small size and variety of colors both of buildings themselves and of the background make tracing of this category extremely heavy. For features small in size red color is useful but only on light and unsaturated backgrounds. If buildings are presented in red, which is one of their traditional cartographic color and woods presented in green as they are, there remains only a question of open ground color. As a background for buildings it should be light and unsaturated, and to hold color contrast with the other two already used, it appears to be a tint of beige, unsaturated yellow.

The four colors selected: beige, pale blue, red and green applied to distinct different categories of objects in the image, realize the first visual level of map design, bringing to foreground the most important information. The image textures show some supportive information about the land use in open ground areas and about diversity in woods.

4.3 Examples

The development of a cartographic approach to the satellite image processing started at the Institute of Geodesy and Cartography in Warsaw, Poland after the copy of Russian KWR-1000 space photograph of Warsaw had been bought in 1993. Original spatial resolution of these images estimated to be 1m was manipulated by Russian authorities to decrease the resolution to about 2m. The black and white panchromatic photograph in scale 1:220 000 was taken from the altitude of 220 km [Csaplovics, 1995]. Actual resolution of the copy bought was lower than 2m. It had been scanned with the resolution of 0.0075mm, 0.015mm and 0.030mm and after comparing the results 0.015 resolution was found to be a limit. The resulting spatial resolution of such digital copy was 3.3m.

The first attempted satellite image map based on this image was the map of Warsaw in scale 1:10 000 from1994. The design was simple. Black and white image resampled and warped to 1:10 000 topographic map was placed in a cartographic frame with grid lines superimposed and some marginal information added. The map met with cool reception despite its high geometrical values. See figure 1.

Figure 1. Satellite map in scale 1:10 000 from 1994.

Second map based on the same image was compiled in 1995 in scale 1:50000 with the aid of SPOT multispectral imagery used for tracing water and vegetation areas. A classification map containing only three classes (waters, vegetation and the rest) was used to color the black and white image of 4 times higher space resolution. . The method applied that time was to use the classification map as the hue component in the intensity, hue, saturation, composition.

The missing saturation component was derived from the image as its negative. A fragment of this map is in figure 2 and in figure 3 there is an inset showing the enlarged part of the main map in scale 1:10 000.

Figure 2. Satellite map in scale 1:50 000 from 1995.

Figure 3. A 1:10 000 inset from 1:50 000 scale map.

The last attempt with the KWR-1000 image was the Satellite Map of Warsaw in scale 1:25 000 compiled in 1996. This is a 4 color map with buildings presented for the first time in red and waters in pale blue with dark blue vignetted band on the edges. The base black and white image was submitted to high pass filtering to reduce tonal contrast and enhance the texture. Colors for buildings, vegetation and waters were derived from the topographic map scanned and classified. Though the map data were in places out of date the resulted map appeared good and met with warm reception. See figure 4. It was printed in 3000 copies with about half of the edition put up for sale. After two years the edition was out of print.

Figure 4. Satellite map of Warsaw in scale 1:25 000 from 1996.

In figure 5 there is a fragment of the map of Warsaw district in scale 1:50 000 compiled in 1998 with the use of slightly the same technology as the previous map. This time the base image was mosaicked from four KFA-1000 photographs of spatial resolution estimated to be 8m. There is a distinction between build-up areas (in orange) and separate buildings (in red). The last examples are selected from the map of Slowinski National Park located on the coast of Baltic Sea in Northern Poland. The map in scale 1:25 000 is based on 29 mosaicked aerial photographs which to some extent might be considered a simulation of IKONOS image with spatial resolution decreased to 2.5m. This is the first map compiled with the use of the possibilities of Adobe Photoshop software. Four masks were traced on the image backdrop (for waters, woods, dunes and buildings) to achieve color distinction between the main categories of objects. See figure 6.

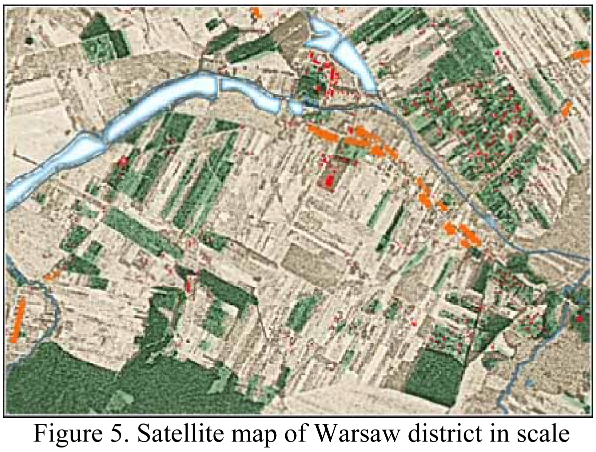

Figure 5. Satellite map of Warsaw district in scale 1:50 000 from 1998.

Figure 6. Aerial mosaic of Slowinski National Park in scale 1:25 000.

Figure 7 shows an attempt to insert the road in a place where it is hidden under the trees: original image (left), image with simple road design (center), image with blurred road (right).

Figure 7. Making a road visible in the image.

5 CONCLUSIONS

It seems unfair to leave the interpretation of the image to the user if it has been done by the specialists at least once. The cartographic approach exploits the result of the interpretation transforming it to colors. The advantage of this manner of image processing lies in preserving the image values making them only more legible. It may develop to a kind of new symbology graphically adequate for the space image environment. The cartographic approach to satellite image map making creates an alternative to the passive processing of the image data. It is intended to be applied in new satellite image maps in scales 1:25 000 and 1:50 000 that are expected to play important role in future topographic mapping.

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