HIGH-RESOLUTION SPACE PHOTOGRAPHY FOR GENERATING AND UPDATING LARGE-SCALE ORTHOPHOTOMAPS

Elmar Csaplovics
Institute of Photogrammetry and Remote Sensing
Technical University Dresden
Mommsenstrasse 13
D-01062 Dresden

Abstract

Russian KFA- and KWR-space photographs fill the gap between medium resolution satellite data (Landsat TM, SPOT) and (CIR) aerial photography. Comparative analysis of spatial and thematic accuracies of digitally processed orthophotomaps based on space photographs and BW-aerial photography show limits and advantages of integrating Russian space photography for generating large-scale orthophotomaps. Mapping heterogeneous landcover patterns needs sophisticated methods of data collection and analysis. Case studies focussed on environmental monitoring of a national park prove, that large area coverage combined with high overall spatial resolution on the one hand but limited spatial resolution in detail on the other are the antipodes of efficiency. Nevertheless KFA- and KWR-space photography represent interesting information for generating and updating medium to large scale orthophotomaps.

1 Introduction

Geometric resolution of current multi-spectral satellite sensors is limited by ground pixel sizes of 20m x 20m (Spot XS). Combination of Spot P and Landsat TM data gives way to improve ground resolution to 10m. BW and CIR-aerial photography is therefore of unchanged importance to satisfy the demands of topographers and ecologists on detection of details of landcover and vegetation structures (stereoscopic interpretation) [2,7].
The missing link between medium to high resolution satellite imagery and very high resolution aerial photography seems to be high resolution space photography represented by KFA- and KWR-photographs of the Russian Kosmos respectively Resurs satellites [14,15].
2mx2m to 8mx8m ground resolution will serve the needs of cartographers and ecologists for mapping heterogeneous landcover patterns and vegetation parameters with increasing accuracies. Correlation of these interpretation results with existing topographic and thematic maps and recent field work fills the recent "information gap" and increases the efficiency of collection, analysis, management and display of multi-scale spatial informations for map production and GIS-purposes up to scales of 1:10000 [11,18].

2 High-resolution space photography

KFA-1000-photographs with the two-layer film SN10 (red, n-IR) and KWR-1000- and KFA-3000-BW-photographs show details up to about 7-8m (KFA-1000: scale 1:280000) respectively 2m (KWR-1000: scale 1:220000, KFA-3000: scale 1:80000). Due to high sensitive B/W-films with a resolving power of 260 l/mm as well as to image motion compensation total resolutions of about 70lp/mm respectively about 1m ground resolution are realistic. Russian authorities manipulate KWR-1000- and KFA-3000-data to decrease resolutions to about 2m , a threshold set by the government with regard to international considerations [3,21].

Nevertheless KWR-1000 and KFA-3000 data represent convincing informations for generating and updating large scale orthophotomaps 1:10000 (table 1).

	KFA-1000	KWR-1000	KFA-3000
altitude (km)	280	220	250
f (mm)	1000	1000	3000
scale	280000	220000	80000
film size (cm)	30x30	18x18	30x30
coverage (km)	80x80	40x40	24x24
$\Delta\lambda_{film}$(nm)	570-670	500-680 (?)	550-770 (710?)
	670-800		
res_{film}(lp/mm)	60 (?)	260 (?)	260
$res_{ground,theor}$(m)	5	0.7	0.3
$res_{ground,real}$(m)	7-8	2	2
cost ($\$/km^2$)	0.30	---	4,30

Table 1: Parameters of current high-resolution spaceborne photographic missions and products

Matching data to a digital land register will only show sufficient results, if pieces of land are large enough. Actually KFA-3000 and KWR-1000-photographs are space-borne remote sensing data with the highest spatial resolution available and therefore important tools to document detailed patterns of landcover and landuse.
Scanning of KFA-3000-diapositives with photoscanner resolution (max.7.5μm) resolves linepairs $\geq$ 80cm ($\approx$ 1.4 $\cdot$ pixelsize) respectively could allow determination of high contrast objects larger than 40cm. Considering positive effects of image motion compensation and negative influences of atmosperic scattering respectively absorption the theoretic accuracy of the KFA-3000-BW-film T-J8 of 260lp/mm has to be reduced to a de facto resolution of about 70-100lp/mm, that is 80cm to 110 cm ground resolution or detectability of objects larger than 40-50 cm under conditions of high contrast between adjacent features. Therefore high-resolution scanning can match the theoretic accuracy of KFA-3000-photographs to a great extent.
Comparative analysis of spatial and thematic accuracies of digitally processed orthophotomaps based on KWR-1000/KFA-3000-space photographs and BW-aerial photography used for the production of the official Austrian Aerial Photomap 1:10000 (ÖLK 1:10000) shows limits as well as advantages of Russian space photography for updating or generating large-scale orthophotomaps.
Planimetric accuracy, elevation accuracy and detectability of objects are the three criteria of suitability of imagery for cartographic uses [13].
Planimetric accuracy can be determined by a value of 0.2mm referring to the required map scale. Focussing a scale of 1:10000 needs an accuracy of 2m, which could be reached by KWR-1000- and KFA-3000-photography, but is actually impeded by spoiling of the resolution by scanning. KFA-1000 photography could be adapted for mapping in scales of 1:50000 and smaller.
Elevation accuracy is the crucial point of usefulness of Russion space photography for mapping purposes. Accuracy values depend on the topography of the terrain - in case of flat (steep) terrain, a contour interval of 20m (50m) is required for a scale of 1:50000, respectively of about 5m (10m) for a scale of 1:10000. As the point measurement accuracy in elevation should be 1/5 of the contour interval, corresponding values of 4m (10m), respectively 1m (2m) cannot be provided by KFA-1000-

space photography. As the test sites of the presented case studies of are located in a very flat terrain, statistically significant research on the reliability of KWR-1000- and KFA-3000-photographs concerning sufficient height accurracy was not systematized till now.
Results of a comparison of accuracies of point determination with space images by bundle block adjustment show, that Russian space photographs (KFA-1000) are a priori not suitable for generating contour lines with accuracies necessary for mapping in scales larger than 1:100000 (Konecny 1994). For KFA-3000 and KWR-1000-photographic data poor base-ratios and low accuracies of measured parallaxes $\sigma_{p\xi}$ will decrease elevation accuracies.
Detectability of objects depends on contrast , shape and texture. Digitized photographs should not exceed pixel sizes of 2m, which are necessary for detecting detailed contents as defined by European mapping standards. As shown above KFA-3000-photographs reach this requirement when being digitized with 7,5μm resolution (Zeiss-PS1), whereas resolution of KWR-1000-data (digital product DD5) is limited by a de facto resolution of about 2.2m to 3.1m ($\equiv$ 1lp, 70-100lp/mm) on the one hand and limits of scanning resolution on the other (1.4 $\cdot$ pixelsize = 2.3m $\equiv$ 1lp).
A summary of these paralipomena can point out the efficiency of KFA-3000- and KWR-1000-photographs for updating details of topographic maps, especially concerning accuracies of X- and Y-coordinates (planimetric accuracy) as well as detectability of objects. On the other hand height measuring accuracies seem to be beyond the information value of Russian space photographs even for a scale of 1:50000.

3 Case studies

Actually case studies focus on multithematic environmental monitoring aspects of a national park situated in the border region of Austria and Hungary about 50 km southeast of Vienna. The so-called Fertõ Tó National Park was established in 1992 corresponding to the criteria of the International Union for Conservation of Nature and Natural Resources (IUCN). Hungarian and Austrian bills have passed into law in 1991 and 1992 respectively.
Primary and secondary zones of the park cover about 150 km². All around these protected zones, wine-growing, single crop farming (mainly maize), exploitation of plots of land for housing and trade as well as for establishing touristic facilities induce fundamental changes of spatial and thematic patterns of landcover.
Environmental monitoring of the National Park itself and of the whole region of Fertõ Tó - Hanság is of growing importance for the documentation of the status quo of landcover and landuse as well as of the multi-temporal dynamics of degradation and the resulting influences on the ecological quality of the protected regions [4].
The synthesis of high-resolution remotely sensed and geo-data is an effective way to create an integrated geographic information system (IGIS) for documentation, analysis, planning and decision finding in the frame of operational aspects of the National Park management [6].
Multi-level remote sensing techniques in connection with field work and mapping are tools for multi-scale analysis of thematic and spatial parameters such as landcover, vegetation physiognomy or distribution of migratory bird habitats [5,19].
Large area coverage combined with high spatial resolution on the one hand but limited spatial resolution in detail on the other are the antipodes of efficiency. Interpretation of KWR- and KFA-space-photomaps for supporting large-scale topographic and thematic mapping (vegetation mapping) show positive results. A synthesis of digital BW-aerial-photomaps derived at about 10-15-year-intervals with annually available digital BW-space-photomaps give an impression of their usefulness for documentation and analysis of multi-temporal dynamics of landscape transition (table 2).

	Aerial Photographs	KFA-3000	KWR-1000	KFA-1000
altitude (km)	4.5	249.8	220	274.8
f (mm)	153.24	2989.46	1000	1000
scale	29400	83500	220000	275000
film size (cm^2)	23x23	30x30	18x18	30x30
coverage (km^2)	6.8x6.8	25x25	40x40	82x82
$\Delta\lambda_{film}$(nm)	350-700	550-710(770)	500-680 (?)	570-670 670-800
res_{film}(l/mm)	100	260	260 (?)	60
distortion (mm)	≤0.005	≤0.1		
$res_{ground,theor}$(m)	0.3	0.3	0.7 (?)	5
$res_{ground,real}$(m)	0.8-0.9	2.0	2.0	7-9
date	16.6.1992	2.8.1993(8:22)	6.1991	12.7.1991(8:22)
cost ($/$km^2$)	1.3 (archive) 13 (new)	4,30	---	0.30

Table 2: Parameters of aerial and space photography analysed for presented case studies

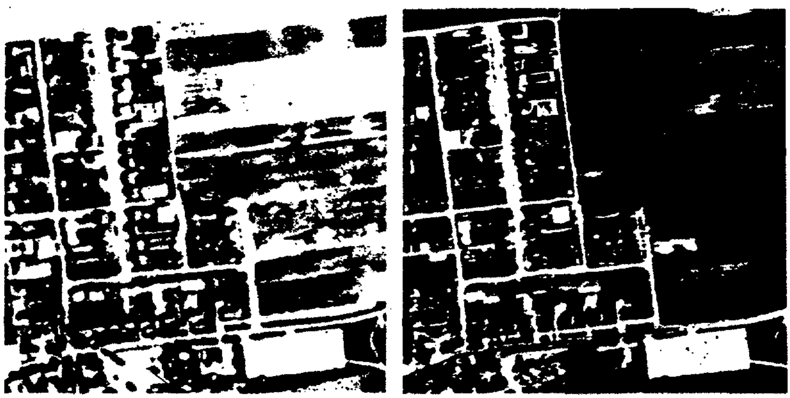

Figure 1: Detail of KFA-3000- (left) vs. aerial photography (right) at a test site, scale ≈ 1:2500

Enlargements of a section of the digitized data (Zeiss PS1, 15μm, pixel size 1.5m vs. 0.45m) of the KFA-3000-space photograph and the corresponding aerial photograph show siginificant differences in grey levels of objects due to different dates of data collection, different film sensitivities and changed landcover patterns (figure 1).
As the B/W-film used with the KFA-3000-system is sensitive in red-edge adjacent near infrared

wavelenghts (770nm vs. 700nm), vegetation and soils are brighter than in aerial photographs. Detectability of geometric features such as small houses is better with aerial photography - limits are set by the artificially spoiled resolution of the KFA-3000-photographs. Selecting higher resolution with the photoscanner shows therefore no siginificant increase in detectability. Overlaying and pseudo-colouring of geometrically corrected images gives concrete informations on locations and thematics of landcover and landuse change.

Considering thematic mapping purposes in scales smaller than 1:25000 a classification of a digitized KFA-data set of the Fertö Tó National Park (Austria, Hungary) improves accuracies of a TM-classification only to some extent. Limits of geometric and thematic analysis of KFA-space photographs are clearly detectable - dependencies on photographic and reproduction processes as well as on hard- and software components of vector-raster transformation restrict classification results to level 2 (object-dependent 3) of the USGS-landuse classification system [1].
Low spectral resolution of KFA-data limits the efficiency of a single data approach. A multi-sensoral approach of combining KFA- and TM-data (Oct.1991) of the region is the tool for minimizing influences of low spectral resolution of KFA-data and of medium geometric resolution of TM-data. Rectification of the combined data set with a pixel size of 10m and classification of data prove a significant increase of accuracy of mapping topography and landcover of the region in a scale of 1:25000. Integration of the multi-sensoral and multi-seasonal data set within a raster-based GIS increases the efficiency of classification and visualization to a further extent. Methods of postclassification using contextual and geometric parameters of the multi-spectral classes of interest reduce influences of misclassification. Classes with characteristic, but heterogeneous patterns can be merged to units of high thematic information potential. The comparison of results of visual interpretation and multi-spectral classification shows some significant differences inside the secondary zones of the Fertö Tó National Park [8], (figure 2).
Field verification of these areas proved the assumption, that due to visual interpretation of CIR- and BW-photography of 1980 respectively 1985, former agricultural lands have been taken on lease by the government during the period 1985-1990 and are actually fallow. Classification of merged high-to-medium resolution multi-temporal remotely sensed data is an efficient approach to analyse landcover change and to control the results of an effective management of the protected regions.

Large scale photogrammetric mapping of landcover change by analysing BW- and CIR-aerial photographs of 1957 and 1985 (photo-scale 1:30000) by means of analytical plotters gives an impression of the unbroken efficiency of very high-resolution photography for multi-purpose mapping in scales $\geq$ 1:10000. Plots of land, houses, roads and paths are detectable. Detailed change analysis of spatial as well as thematic patterms is useful for updating the Austrian orthophotomap 1:10000, but also for supporting updates of cadastral maps. Environmental aspects are documented by the evidence of agricultural use inside primary zones of the national park (dotted areas, figure 3).
Multithematic demands on a spatial monitoring system can be met by the presented way of map-conform, land register-accurate large scale monitoring of confrontation zones between conservation strategies and agricultural landuse. Using facilities of geographic information systems digital mapping of multi-temporal dynamics of landuse is a tool for compiling change detection maps [7,9].

Based on the very high-resolution approach presented above a collection of multi-sensor space photography for the same test site was established (see table 2).
Limits of spatial and spectral resolution of digitized KFA-photography (pixel size 30μm) for mapping in scales 1:10000 are evident. On the other hand digitized KWR-1000- and KFA-3000-photographic data (pixel size 15μm) show topographic and thematic details comparable to the information content of aerial photography (see figure 1).

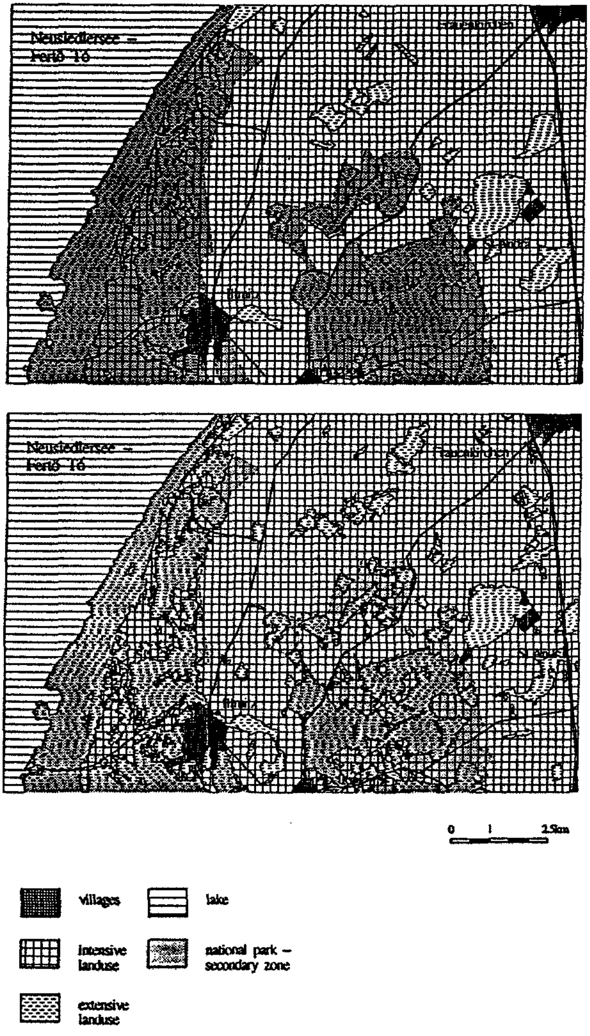

Figure 2: Maps of extensive versus intensive land use, aerial CIR-photo- and aerial BW-orthophoto-interpretation (top), classification of a Landsat TM - KFA-1000 multisensor image (bottom) [8]

Figure 3: Test site Illmitz/Kirchsee, digital maps of landcover 1957 (left) and 1985 (right), aerial photo-interpretation with analytical plotter, map scale 1:10000 reduced to M ≈ 12500 [7].
Classification key: 11 - water, 12 - littoral, 13 - reed, 14 - grazing lands, 21 - vineyards, 22 - fields, 31.. - housing (VNSG - primary zone of national park, BL - residential)

This approach is restricted to certain photo-object groups, which are characterized by easily detectable spatial and/or spectral textures or patterns and by significant contrast differences of adjacent features. Combination of KWR-1000- and KFA-1000-data for optimizing both geometric and spectral resolution proofs, that multi-sensor digital spacephoto-maps can meet requirements for thematic interpretation of orthophotomaps 1:10000. In the thematic case they even seem to be more efficient than BW-orthophotos based on panchromatic films with limited spectral detectability. On the other hand planimetric accuracy is decisively decreased by KFA-1000-data (figure 4).

Multi-temporal analysis of landcover change is of urgent need for updating spatial and non-spatial informations for maximizing reliabilities of decisions for regional planning and protection. High-resolution digital KWR-1000-orthophotomaps can be merged with digitized landcover maps derived from stereoscopic analysis of "historical" aerial photography. Comparison of a detail of the KWR-

1000-data of the test site Illmitz/Kirchsee combined with a GIS-layer of landuse in 1957 (analogue aerial photointerpretation) documents patterns of change for a time interval of 34 years.

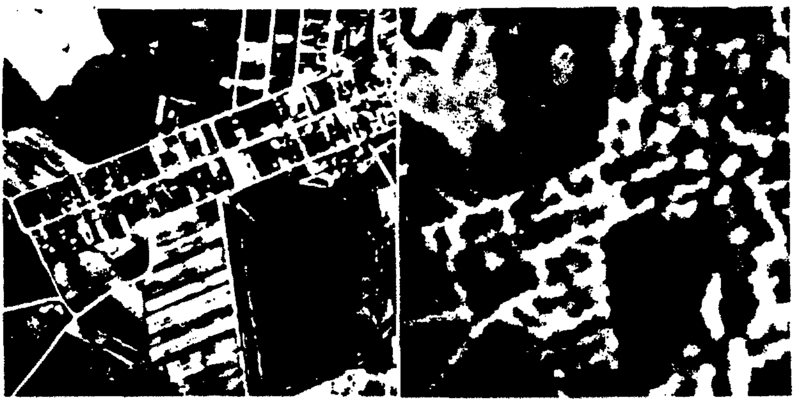

Figure 4: Test site Illmitz/Kirchsee, detail of KWR-1000-space-ortophotomap 1:10000 (left) and KFA-1000-georeferenced digital data, scale ≈ 1:13000 (right) (for comparison see figure 3).

Conclusio

Vector to raster conversion reduces precision levels of maps and induces incorrect specifications of the relationship of map classes and remote sensing multi-spectral thematic clusters [10].
Landcover change detection based on remote sensing systems depends on spatial, spectral, radiometric and temporal resolution parameters [12].
Multi-level monitoring of heterogeneous landscape patterns of either urban, rural or semi-natural vegetation needs well-defined interpretation methods [16,17,22].
Depending on the structure of data - on the one hand vector data of visual interpretations of aerial photographs or satellite image prints, on the other hand raster data of digitized photographs and scanner images - different a priori approaches for topographic and thematic subdivision of areas and/or regions are available.
For ecological purposes the hierarchical structure of regions implements regionalization of data based upon the holistic understanding of ecosystem analysis [20].
Multi-spectral classification of raster data of satellite sensor systems is sometimes interpreted as an objective criterium of object detection and areal subdivision. Nevertheless accuracies of in praxi research proof the subjectiveness of results depending f.e. on efficiency limitations of automation of landcover pattern recognition and texture analysis or on the various reference levels of analysts when choosing training samples for various steps of mapping and classification [5].
Updating orthophotomaps needs surveys in time intervals of 2 years. Costs for aerial survey missions are high (see table 2). Compiling updates of landcover and landuse in regions of dynamic pressure on

the land requires high-resolution space orthophotomaps based on panchromatic KWR-1000- and KFA-3000-data eventually and supplemented by n-IR-spectral informations of KFA-1000-data. Costs for data acquisition are low compared to aerial survey missions - a factor of 1:3 is realistic even when calculating costs for a multi-sensor KFA-1000/KFA-3000-data set.

Costs for thematic surveys for landuse or topographic (cadastral) mapping based on aerial photography are estimated to be as high as 520$/km^2 respectively 400$/km^2 [13].

Following the case studies presented above it seems to be realistic to minimize costs when using digitized photographic data of Russian space missions for production and planimetric as well as thematic updates of maps 1:10000. As pointed out, efficiency of these data is limited by very low elevation accuracies attainable.

High-resolution space photography could be an important tool for optimizing temporal resolution of aerial photomaps. Dynamics of urban growth, cultivation and environmental quality are bound to a temporal resolution of topographic and thematic map information of less or equal to a year. Traditional methods of map production are based on revision intervals of about 10 years. Digital space-orthophotomaps are therefore the "missing link" to actualize topographic and thematic maps without high financial and/or organizational outlays.

The future has to face the limits determined by problems in operational distribution of data by Russian agencies. On the other hand operational space-borne CCD-systems with spatial resolution of 1m have been announced by U.S.agencies for 1997. This gives, to a further extent, an impression of forthcoming perspectives of increasing mapping accuracies both spatially and temporally.

In the year 2004 a total of about 78 space missions will include about 40 missions focussing on land and ocean monitoring. Needs for optimizing data retrieval from vast data pools, for establishing efficient meta-data base management systems and for decreasing the relation between costs and specific information demands by operationalization of thematic information extraction are evident. Furthermore misuse of data by merging heterogeneous spatial and non-spatial raw data will increase the world-wide distribution of incorrect cartographic informations - the question has to be asked again and again: what do we need to know, and how well do we need to know it.

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