USE OF LANDSAT 7 ETM+ DATA
AS BASIC INFORMATION FOR INFRASTRUCTURE PLANNING

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ABSTRACT:

To improve the infrastructure of a region, the existing features such as settlements, roads, railways and waterways have to be documented completely. In developing countries this basic information is often missing, incomplete or obsolete. To use automated segmentation algorithms (multispectral / knowledge based classification) with satellite data, geometric resolution, spectral bands and processing techniques are the most important parameters to get an optimal result. The aim of this investigation is to analyse how Landsat 7 ETM+ data can be used for this purpose. Especially the new panchromatic band with its higher resolution is examined in combination with the multispectral information and additional layers (e.g. vectors) as artificial bands. The main results of the investigation are as follows: The separation of settlement areas is without problems. The detection of linear features is not satisfying in the used test area with a domination of less contrast. The integration of the panchromatic band conduct an improvement of less than 10% in accuracy assessment. A practical solution which leads to an acceptable result is to integrate visually digitised vector information as an artificial band into a hierarchical classification algorithm.

1. INTRODUCTION

1.1 General

Before starting a countrywide infrastructure planning mostly in developing countries, a comprehensive data base of the existing situation has to be established first. Concerning the use of satellite images, the term of infrastructure has to be reduced to human settlements, roads, railways and waterways which has to be detected.

To use automated segmentation algorithms (pixel based multispectral / knowledge based classification) with satellite data, geometric resolution, spectral bands and processing techniques are the most important parameters to get optimal results.

Today a multitude of sensor systems for small-, medium- and large-scale application is available. As the cost for one sqkm of multispectral or panchromatic images seems to be at least a square function of geometric resolution, it is not unimportant for large areas to find out the necessary and sufficient system which meets the named requirements.

In this context Landsat 7 ETM+ data are used for the first step of such an investigation. Especially the panchromatic band with its higher resolution is examined in combination with the multispectral information and additional layers (e.g. vectors) as artificial bands.

As orthophotos represent a basic planning tool, a preliminary examination is carried out to analyse different merging techniques. The main part of the investigation is concentrated on a pixel-based multispectral classification and a knowledge based classification in reference to the available information of a test area.

1.2 Analysis of Image Data

Concerning the geometric resolution the Landsat system ranges at the lower end of systems for topographic mapping and land use applications, but it is leading in spectral resolution (number of spectral bands). With the panchromatic band (PAN) a more detailed extraction of information could be expected without introducing a second system (e.g. SPOT).

Table 1 shows ground resolutions and band widths and their ratios of panchromatic to multispectral of three satellite systems.

System	Ground-Res. PAN (m)	Ground-Res. Multisp. (m)	Ratio Ground-Res. (Ground-Area)	Band-Width PAN (µm)	Av.Band-Width Multisp. (µm) (VNIR)	Ratio Band-Width
Landsat 7 ETM+	15	30	1:2 (1:4)	0,38	0,09	4:1
SPOT 5	5	10	1:2 (1:4)	0,23	0,11	2:1
Quickbird	0,61	2,44	1:4 (1:16)	0,45	0,09	5:1

Table 1: Ground-Resolutions and Band-Width Ratios between PAN and Multispectral bands.

Whereas the band width of the multispectral channels are nearly identical (approx. 0,10 µm), the PAN band widths differ strongly. They cover between two and 4 multispectral bands.

The ratio of the ground resolution is in the range of 1:2 to 1:4 with a correlation to the band width according to the increase of the reflected radiance energy with increasing band width. Comparing the band width of the Landsat 7 PAN channel, a better ground resolution should be reached.

The second aspect is, that the PAN bands of the different systems are not completely congruent to the visible spectral area of their multispectral bands which is important to consider in image fusion techniques (Figure 1).

Landsat 7 PAN (as well as Quickbird) integrates the NIR band in opposite to SPOT 5 and is rather congruent to bands 2-4, which are used for CIR (colour infrared) visualisation.

Compared with the standard combination SPOT Pan/Landsat the combination Landsat PAN/Landsat will differ strongly not only in resolution but also in colour presentation.

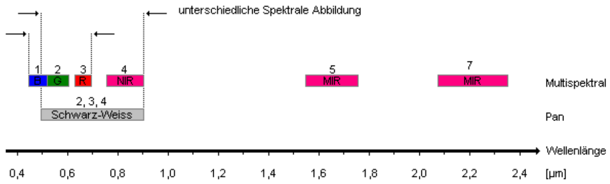

Figure 1: Landsat 7 ETM+: Dissonance between PAN band and VIS multispectral bands.

2. ORTHOPHOTO PRODUCTION

2.1 Orthophoto Process

The evaluation of different merging techniques was carried out in the final product of an orthophoto. For this purpose a subset of a Landsat 7 scene (196/024) of 17x56 km was chosen south east of the German "Ruhrgebiet". This area covers two tiles of SRTM elevation data, which were used together with a digital topographic map in the rectification process (Schmitz, 2004).

2.2 Merging Techniques

By merging the PAN channel with its higher ground resolution with multispectral bands of lower resolution the more detailed geometry of the PAN band and the spectral information of the multispectral image are fused in the merge product.

For merging the Landsat 7 bands different methods were tested:

1. Statistical methods: Principal Component Analysis (PCA).
2. Numerical methods: Multiplicative and Brovey.
3. Colourspace transformation with wavelet decomposition (wavelet - IHS-Transformation).

In the bibliography a lot of papers deal with this merging techniques with the aim to avoid strong colour shifting (e.g. Chavez et al. 1993, Pellmanns et al. 1993). According to the mentioned situation, that the PAN bands are individual in the different systems, the results of using merging techniques in between the Landsat system must be of interest.

2.3 Merging Results

To receive a true colour orthophoto by merging the visual spectral bands (1-3) with the PAN channel, all merging methods show strong colour shifts as expected, except the method done by wavelet-IHS transformation. By this method the coefficients of the PAN and multispectral image are matched in the wavelet domain to keep the multispectral information (Chibani & Houacine, 2002, Shamshad et al. 2004). Similar methods based on frequency or wavelet transformations are described in the literature (Ehlers & Klonus, 2004, King & Wang, 2001).

To solve the problem with the other methods, the merging process was repeated using the multispectral bands 2-4 which are rather congruent to the PAN band. The results are then transformed to "natural colour" by introducing an additional synthetic blue channel. The best results in this test are achieved by the PCA transformation. In contrast to the wavelet-IHS result the colours look more artificially. The results of the two numerical methods (Multiplicative and Brovey) are not very convincing.

Figure 2 shows the best results of merging techniques together with the original unmerged true colour composition of the multispectral bands.

In summary the best pansharpened true colour image can be achieved by the wavelet-IHS method, followed by PCA Transformation with additional true colour transformation.

In general the benefit of the pan merged orthophoto to detect more detailed infrastructure elements by visual inspection is limited.

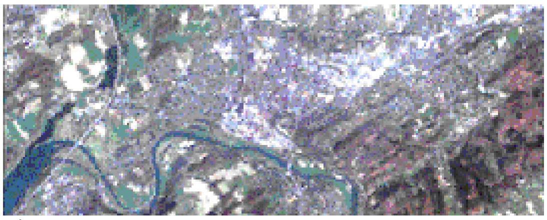
Figure 2a

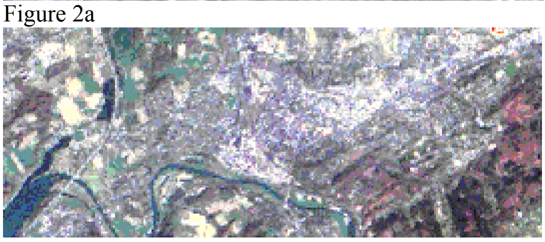
Figure 2b

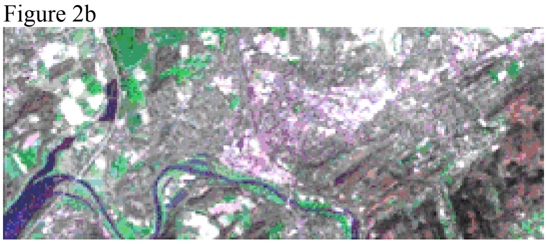
Figure 2c

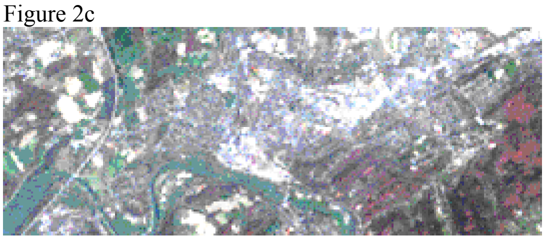
Figure 2d

a: True colour composition of original multispectral bands (1-3). Ground resolution 30m.

b: Resolution merged image by Wavelet-IHS Transformation (PAN + 1-3). Ground Resolution 15m.

c: Resolution merged image by PCA-Transformation (PAN + 2-4) and Natural Colour Transform. Ground resolution 15m.

d: Resolution merged image by PCA-Transformation (PAN + 1-5,7). Ground Resolution 15m.

3. MULTISPECTRAL CLASSIFICATION

3.1 Processing Landsat 7 Data

With 6 multispectral bands Landsat 7 data are predestined for multispectral classification. But the ground resolution of 30 m doesn't seem to be good enough to detect linear infrastructure elements. So most of the investigations in this field uses images of a better geometric resolution and don't use the spectral information (e.g. Mukherjee et al., 1996). In the following text different data sets with the integrated PAN band on a base of 15 m ground resolution are tested versus the original multispectral

data and in relation to an existing infrastructure layer of a digital topographical map (DTK 100).
Standard classification algorithms for pixelbased unsupervised, supervised and knowledge based classification are used to extract settlements and linear infrastructure objects.

3.2 Band Combinations

For the multispectral classification the following band combinations were chosen and tested:

Set	Band Combinations	Reso-lution
B1	Reference Data (1,2,3,4,5,7) original spectral bands	30 m
B2	Spectral Bands with PAN (1,2,3,4,5,7 + PAN) PAN band combined with all 6 spectral bands as 7th independent channel	15 m
B3	Wavelet-IHS-Transformation (1,2,3 + 4,5,7 IHS) 2 Groups of 3 spectral bands merged with PAN band by wavelet-IHS	15 m
B4	PCA-Transformation (1,2,3,4,5,7 PCA) 6 spectral bands merged with PAN band by PCA	15 m
B5	Multiplicative (1,2,3,4,5,7 Multiplicative) 6 spectral bands merged with PAN band by Multiplicative method	15 m
B6	Resolution-Merge-Brovey (1,2,3 + 4,5,7 Brovey) 2 groups of 3 spectral bands merged with PAN band by Brovey method	15 m

Table 2 : Band Combinations for Multispectral Classification.

3.3 Supervised and Unsupervised Classification

In the multispectral classification both methods Unsupervised & Supervised Classification were combined in the *Interactive Process* (Albertz 2001). For this process the infrastructure objects were classified by Supervised Classification, the other unimportant classified objects such as wood and agriculture were classified by the Unsupervised Classification with *ISO-DATA Clustering method* (ERDAS Field Guide, 2003) and pooled in one class as unclassified. The choice of training areas for the infrastructure objects was concentrated on highways, major roads, railways and urban areas. A previous classification test showed, that a separation of this features, especially of the linear ones, in different classes is not indicated. Altogether about 20 training areas were determined.

3.4 Results

The classification results of the different band combinations are presented visually in Figure 4 and are discussed in the next chapter.
To prove the accuracy of the classification results an accuracy assessment was implemented for the infrastructure class. Different results for the band combinations were achieved (Table 3, Figure 3).

	B1	B2	B3	B4	B5	B6
Accuracy	72 %	61 %	76 %	74 %	55 %	51 %

Table 3: Classification Accuracy of band combinations.

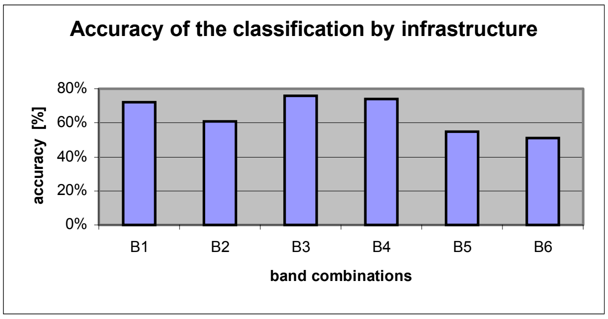

Figure 3: Infrastructure Classification Accuracy of different Band Combinations.

3.5 Conclusions

The visual comparison and the results of the accuracy assessment leads to the following conclusions:
The use of the pan band as independent channel doesn't show any kind of improvements in the classification results in spite of a better resolution. Good results can be achieved with the two pan-merged data sets IHS and PCA. But these evaluated results are not much better than the results of the reference data.
The results of the Brovey & Multiplicative method are very insufficient. In this case the spectral variation at the merge process of both merging methods take a negative effect.

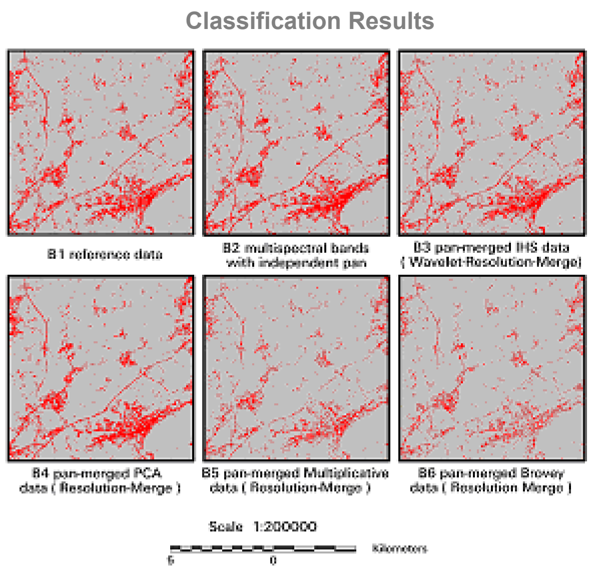

Figure 4: Classification with different band combinations.

In Figure 5 one of the best results (Double Wavelet-IHS-Transformation) is copied together with the map infrastructure layer for an absolute comparison.
The comparison of the results with the DTK 100 layer show that the classification results are geometrically correct, but incomplete in presentation of linear infrastructure objects.
The panchromatic band of Landsat 7 offers with its higher resolution of 15 m in relation of mapping of linear infrastructure objects by a pixelbased multispectral classification only very

few advantages. Linear infrastructure objects such as roads, with a width of less than 30 m (about 10 m, RAS-Q 1996), can only be represented by isolated single pixels in spite of the higher resolution of 15 m. This is not sufficient to recognise the object by pixel connection like it is possible with the highway class (width about 30 m, RAS-Q 1996). Aside from the resolution the PAN band of Landsat 7 offers with its spectral range (bands 2 – 4) no additional spectral information to increase the classification accuracy.
At the moment the results of this investigation have to be limited to similar types of terrain with completely covered areas and medium to less contrast. An extension is planned to test also arid and tropical areas in regard to developing countries.

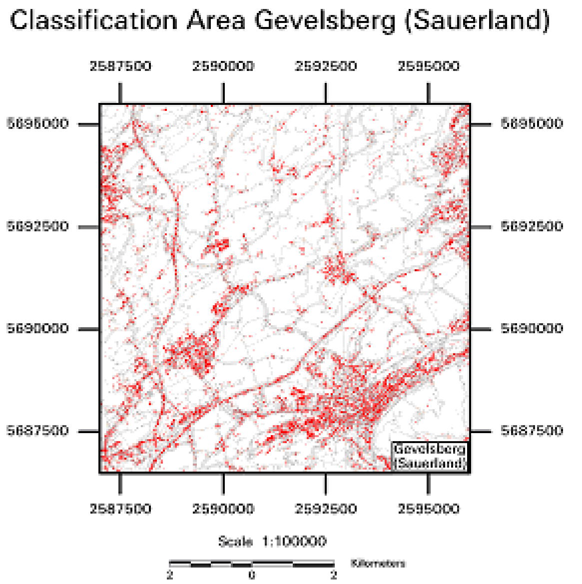

Figure 5: Classification with wavelet-HIS merged data set combined with infrastructure layer of DTK 100.

4. KNOWLEDGE BASED CLASSIFICATION

4.1 General

As seen, the inclusion of the PAN band into a standard multispectral clasification doesn’t offer essential improvements. Other investigations with automated detection of lines and their connections show that the extraction is rather incomplete (Taniguchi & Kawaguchi, 1989, Dech et al., 2003). For this reason a practical approach was established to introduce visual vector digitising as an artificial band into a knowledge based classification algorithm. By that means the human ability to identify shapes and connectivities will be introduced in the automated process.

4.2 Vector Digitising

For this investigation a vector-digitising was practised in the PAN band, the reference data and the wavelet resolution merge IHS data. Altogether three infrastructure objects of traffic (highway, major road & railway) were chosen.
Therefore several traffic segments were digitised, which where recognisable by a good contrast such as major roads outside of urban and forest areas. The digitised vectors were transformed into raster data and defined as 3 artificial channels.
To evaluate the completeness of the digitised segments, a reference size is needed. This reference size was received as the overall length of the different 3 classes in the test area by the DTK 100 layer The digitised segments were determined as percentage to the reference size.

	Highway	Major Road	Railway
PAN 15m	100 %	40 %	50 %
Wavelet-IHS 15m	100 %	33 %	50 %
reference data 30m	100 %	33 %	50 %

Tab. 3: Completeness of visual vector-digitising of 3 linear infrastructure classes.

The results show that the PAN image offers a moderate advantage in comparison to the multispectral reference data in representation and mapping major roads. The merged wavelet-IHS image offers no significant improvements in comparison to the reference data.
As for the absolute percentage of the detection of major roads and railways, only really visible segments were digitised as already mentioned. The percentage can be improved quite a lot by digitising securely assumed continuations of lines in canopied and urban areas.

4.3 Hierarchical Classification

After the visual vector digitising a Hierarchical Classification was carried out. The evaluated raster data sets of the three infrastructure classes were used as artificial bands together with the merged wavelet-IHS data as best result of the preceding multispectral classification.
Figure 6 shows the final result of the Hierarchical Classification with the double panmerged wavelet-IHS data set and digitised vector data.

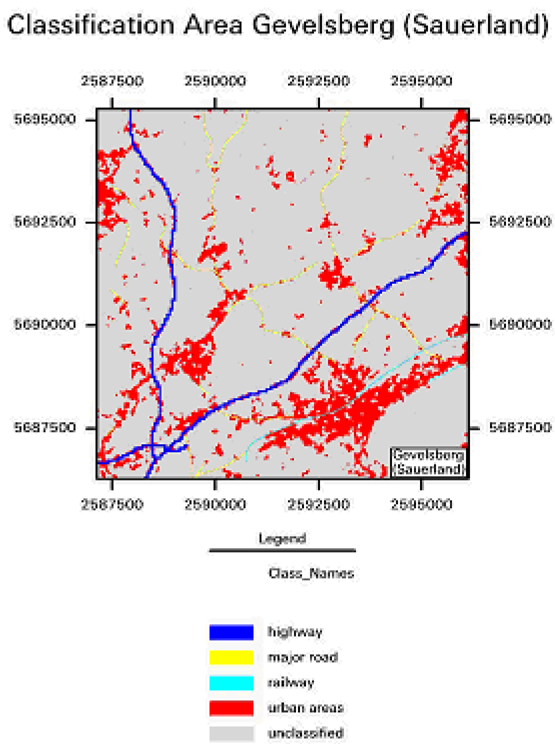

Figure 6: Hierarchical Classification with double panmerged wavelet-IHS image data and digitised vector data.

The combination of the multispectral classification and the visual vector digitising seems to be a good solution to improve the classification results for infrastructure objects in Landsat

images. On the one hand settlement structures and main traffic lines can be extracted automatically, on the other hand information of smaller linear objects (e.g. roads & railways) can be added by a visual interpretation to the same data set.
Nevertheless the evaluated vector data are partly incomplete according to the relations of object size, resolution and contrast. Under normal conditions of contrast a complete presentation of linear infrastructure will keep difficult in spite of the inclusion of the PAN band of Landsat.

5. SUMMARY

The investigation of the Landsat 7 bands has confirmed that the production of fused images, such as pansharpened orthophotos, it is necessary to heed the different character of frequencies or wavelet coefficients in the transformed PAN image and in the intensity or component part of the transformed multispectral bands by a sophisticated fusion algorithm which keeps the specific information of both data sets.
It has also proven, that merged products are not significantly better for visual detection of linear infrastructure objects. This could be done best in the original PAN image, because one has to consider, that walking at the border of perception of an object, every interpolation procedure could destroy this details.
In the resolution domain of 15 to 30m and a moderate contrast, manual digitising of thin linear object cannot be replaced by multispectral classification. A Hierarchical classification, merging the vector information with the classification results has proven as a practicable solution.

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