Feature Extraction for Map Based Image Interpretation

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Abstract

Images taken from satellite or airborne platforms usually do not represent isolated information of man's environment. In most countries, additional data bases are available which may be integrated successfully in the image interpretation procedure.

The paper outlines a research project under way at the Institute for Photogrammetry and Remote Sensing at Karlsruhe University, Germany. Digitised topographic line maps in 1:5000 serve as ancillary data for image interpretation in 1:6300. Object classes are man-made features of different types and land use. The procedure seems to be very useful as soon as it works operationally, since in the near future all conventional topographic line maps in Germany will be available in digital form (ATKIS = 'governmental topographic/cartographic information system').

Specific problems involved in the interpretation process are visualised and first results are presented.

1 Introduction

It is expected that in the near future Geo-Data will be available in digital form. As we all know, this is not yet generally the case except for Satellite Remote Sensing Imagery. At the moment most cartographic national bodies are establishing digital data bases of conventional topographic maps in vector form. This is not only true for Germany (see e.g. [3]) but also for other countries. In photogrammetry, too, we observe a tendency from analog to digital imagery. The international community of surveyors, cartographers, photogrammetrists and Remote Sensing experts have to be aware, that not only the procedures, but also the complete data sets will be digital.

There may be many arguments in favour of digital data processing in the Geo-Domain. The most relevant one is *automation*. This does not mean to substitute the human operator, but to support his work.

The presented paper shows a segment of the research line at the Institute for Photogrammetry and Remote Sensing at Karlsruhe University. It focuses the *interface* *of map and images*, i.e. digital data bases, attributes, geometry, semantic contents and aspects of data processing. The philosophy is that both imagery and maps are of same nature. Both products do not describe the 'real world' sufficiently well. But one may support the other for semantic data extraction and update.

The intimate interrelation between maps and images has to be generally recognized. The paper describes a research work not yet completed, which tries to compare both data schemes using semantic networks.

2 Importance of Map-based Image Analysis

Some realistic examples from the test area will show that neither image information, nor map information at its own may provide a complete, 'realistic' image of the real world. For this special purpose the available data are presented first.

The methodologies for map-based verification and recognition of objects are developed for urban scenes. As a test area, a sector of the urban environment of the city of Karlsruhe was selected, which contains both typical metropolitan densly constructed areas as well as extended park and forest areas.

2.1 Image Data

The digital image data were acquired by scanning aerial colour photographies of 230 by 230 mm. The aerial images were taken from a flying height of 2 km, having a scale of 1:6300 and from a flying height of 6 km, providing a scale of 1:40000. Scanning of the photography was done with 50 μm and a grey value resolution of 8 bit.

2.2 Map Information

The context information was acquired from a topographic map, the German Topographic Base Map 1:5000 (Deutsche Grundkarte DGK5 1:5000, [1]). The corresponding sector to the aerial images was acquired by manual digitalization of the contours at a digitizer tablet and was stored in the data base of GIS ARC/INFO. The registered contours are available as a coordinate list in the Gauß-Krüger Coordinate System and were assigned to the following 11 classes: single house, tower block, big building, parking area, playground, courtyard, forest, garden, street, mainstreet, lane.

Figure 1 shows a section of the image and the corresponding map section.

2.3 Comparison Map Information - Image Information

The transformation parameters between the coordinate systems of the images and the world coordinate system are determined by an adjustment from the ground con-

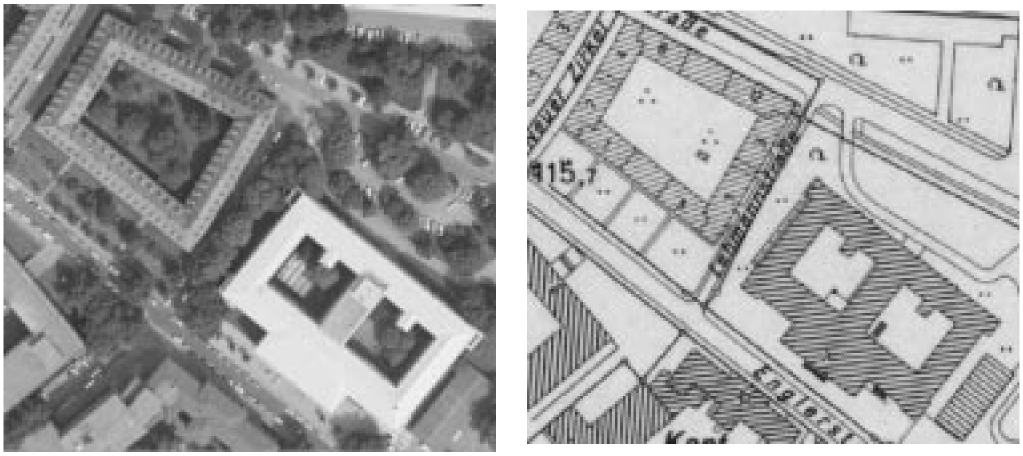

Figure 1: Section of the aerial image (left) and the corresponding map section.

trol coordinates. Selection and assignment of ground control points in the image to the respective points in the map is done interactively. The transformation parameters allow to project the map information onto the image. Figure 2 shows the digitized contours from the map as an overlay (white lines) for the selected example in Fig. 1.

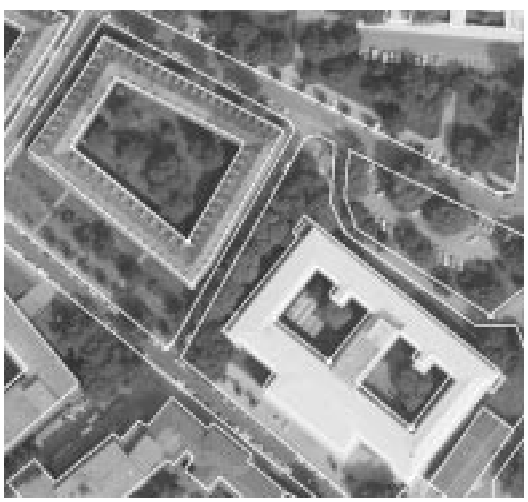

Figure 2: Extract from the aerial image with map information as overlay (white lines)

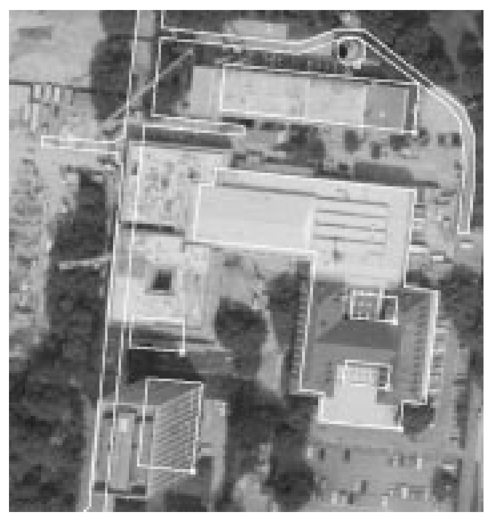

Figure 3: Differences between the aerial image and the map information (white lines as overlay)

This examples shows, that the object borders acquired out of the map are not at all identical with the contours visible in the image. There are multiple reasons for this effect:

- The map does not include height information. Therefore transformation parameters were only modelled on a 2D-base.

- The perspective distortions in the image, which are extrem especially for tall buildings at the image borders.
- The map shows the ground plans of the buildings, whereas in the images the border lines of the roofs are visible. They necessarily do not fully match. In addition to the other errors mentioned, this yields to a geometrical shift of 2 to 3 pixels for the selected resolution
- Inaccuracies during the digitalization and ground control point determination.

Due to the different acquisition date of map and image, beyond the allready mentioned differences, there are also differences because of the changed reality. These differences are frequent in build-up areas, especially due to activities in construction. Figure 3 presents such a case: A nearly completed building is not yet shown in the map; the small building shown in the map at the respective place does not exist any more. Because of the building activity the street pattern changed too. After all, the big difference between the position of the tall building in the map (lower left part of the image) and its visible lines in the image is remarkable. The central perspective of the image leads to an overlap of the tall building and the road.

It turns out, that both map and image provide a reduced and partly wrong image of the reality. In general, aerial photography is more economic and faster than the production of new maps. Therefore automatic updating of maps on the basis of aerial images seems to be desirable. However, the map itself in its digital form as a (uncomplete) model for image interpretation has to be available.

3 Edge extraction

During the interpretation process we are using region–based and edge–based features. In the following we'll present our approach for edge extraction. Edges can directly be related to the map information, which is available in form of lines.

In order to approximate the contours in a grey value image by lines, the following steps are taken:

1. Filtering of the image in order to acquire contour points.
2. Selection of contour points
3. Chaining of the selected contour points
4. Segmentation of the selected contour point chains
5. Approximation of the segmented contour point chains by piecewise lines.

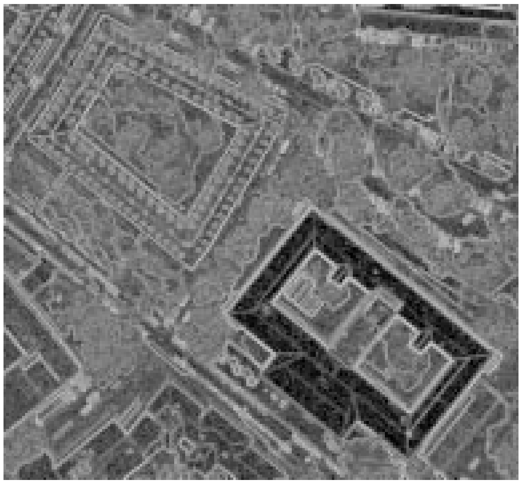

Figure 4: Gradient magnitude image

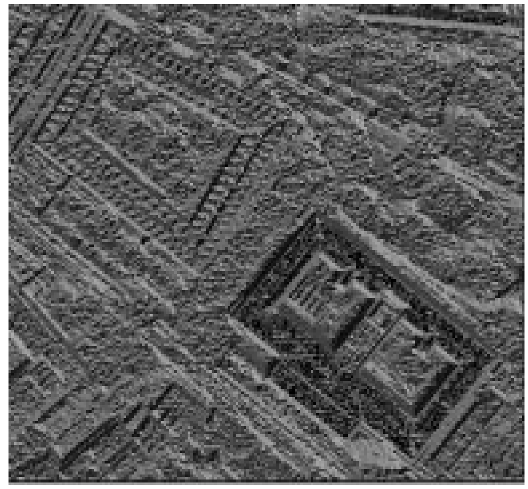

Figure 5: Gradient direction image

3.1 Image Filtering for Contour Point Extraction

In order to extract the contour points out of the grey value image, it is convolved by a gradient operator. For this the NAG-operator was taken (*N*ormierte *A*bleitung einer *G*außfunktion,[4]). It is well suited to find changes in grey values of low slope and variable width. Convolution by this operator combines low–pass filtering of the grey value image for noise reduction with a differentiation in x and y. One parameter is required: the standard deviation of the gaussian, which was used to produce the operator. This parameter determines the extension of the NAG-operator and is adapted to the width of the grey value slopes.

This step applied to the grey value image results in the gradient magnitude (Fig. 4) and the gradient direction image (Fig. 5). The gradient directions in Fig. 5 are grey value encoded with a resolution of 2 degrees.

3.2 Selection and Chaining of Contour Points

For describing the edges in the image by piecewise lines, it is useful if the contour point chains following the edges have a width of one pixel. Besides this, values of the gradient, which had been produced because of noise, should be reduced as early as possible. Only those contour points are selected, which show a local maximum for the gradient magnitude in the gradient direction and at the same time exceed a given threshold.

The selected contour points are registered and stored in lists. A contour point chain is a list, which contains adjacent contour points.

For chaining the contour points, a contour following algorithm is applied, which allows to close small gaps in the lines. For this, the information from the gradient

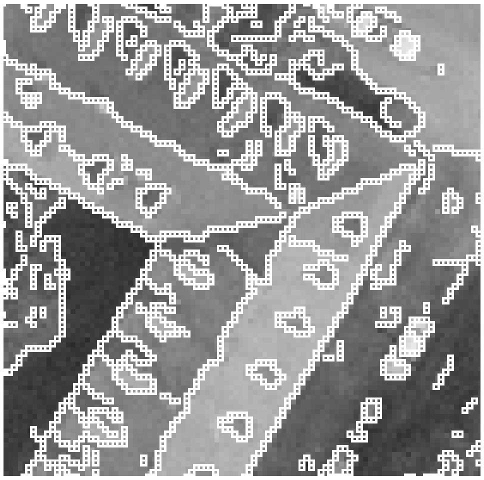

Figure 6: Enlarged detail of the image with superimposed contour points

Figure 7: The extracted edges are overlaid as white lines on the aerial image

value and the gradient direction image is used. A parameter controls the width of the gaps to be closed. In general gaps up to 3 pixels are eliminated.

Figure 6 displays the contour point chain superimposed to the aerial image.

3.3 Segmentation of the Contour Point Chains

The contour point chains are segmented for later approximation of linear contour segments by lines. In this case we understand segmentation as partitioning the chains in subchains with different curvature.

For segmentation, the local directions of the gradient at each contour point are analysed. The difference of the directions of two adjacent contour points is a good approxiation for the curvature of the contour at this position. A straight line is a curve whith zero curvature. The contour point chain is segmented at points with local maxima of the curvature.

3.4 Approximation of the Segmented Contour Point Chains by Piecewise Lines

After segmenting the contour point chains, the curvature along this chain doesn't exceed a given threshold. We can now approximate this contour point list with a line, using a least square approximation technique: the mean square distance of the chains contour points to the line looked for has to be minimum.

Let g be the line looked for. Then it's equation in hessian normal form ([2]) is:

$$g: \quad ax + by + c = 0 \tag{1}$$

with

$$a^2 + b^2 = 1. \tag{2}$$

The squared distance of a point $P(x_0, y_0)$ to the line g is given by:

$$d^2 = (ax_0 + by_0 + c)^2. \tag{3}$$

This yields for the function to be minimized, using equation (2) as constraint:

$$F(a, b, c, \lambda) = \frac{1}{n} \sum_{i=1}^{n} (ax_i + by_i + c)^2 + \lambda(a^2 + b^2 - 1) \tag{4}$$

Minimizing the function $F(a, b, c, \lambda)$ yields the parameters a, b, c of the line g, which approximates best the segmented contour point chain in the sense of minimum square errors.

Fig. 7 shows the line segments found this way as an overlay on the grey value image.

4 Verification and Interpretation of Image Data

The map-based analysis of image data is done by comparison of models. The semantic network ERNEST [5] is used for modelling general knowledge for urban scenes and knowledge for the specific scene to be analysed. ERNEST serves as the central control component, too.

The semantic network contains two different types of knowledge: declarative and procedural knowledge. The declarative knowledge contains concepts and links (part-of, concrete, specialization and instance links), which determine the relation between the concepts. The procedural knowledge contains methods for computing the attributes of concepts as well as assessment of concepts and of the relations between them. The assessments drive the problem independent control algorithm.

As a basis for the interpretation task, a semantic network which contains general knowledge for the scenes to be analysed is used. This network does not yet contain knowledge for the transformation of the scene into the map sector or the image sector. In a following step two semantic networks are build, which contain specific knowledge for the analysis in map sector and image sector. By this step mostly procedural knowledge is added to the networks.

Map analysis using the semantic network for map sector yields a model of the scene actually to be analysed. This specific knowledge for the scene to be analysed together with the network for the image sector is automatically transformed in a specialized semantic network for analysing the actual scene. This last mentioned net finally will perform the image verification and interpretation task and assign a meaning to the extracted features.

5 Conclusions

In this paper, we presented a project under way for image interpretation using contextual information from topographic maps. After describing the problems that emerge when combining image and map information, we presented the approach used for edge extraction from aerial images. This way extracted features are used by a semantic network in the image interpretation task. The semantic network for image interpretation is automatically build from the results of a previous map analysis.

Further work has to be done for incorporating region-based features in the interpretation task and for improving the procedural knowledge of the semantic network in the image sector.

References

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