TOPOGRAPHIC FEATURE EXTRACTION BASED ON CONTEXT DEPENDANT FILTERS.

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ABSTRACT

In the process of updating maps and databases using remotely sensed data the fast and efficient extraction of topographic features is addressed here. Non-linear filters are used for the detection of linear features and for the segmentation of the images into differently textured fields. Our structural approach using symbolic structure elements is implemented on the BOP Binary Operator Processor by ContextVision.

INTRODUCTION

With the enormous backlog of up to date maps and the increasing need for "maps" or data sets which provide specific answers to users, there is a need to speed up the extraction of topographic features and the classification of thematic features.

We do not envisage a complete take over by the computer, but we expect that a substantial part of present manual work can be replaced by digital processing in the near future. The remaining interaction will be at an editing and decision making level, such as during the classification of detected (linear) objects, but also during the guidance of the process. Less time will have to be spent in manually tracing lines and object boundaries.

In the following, we mainly report on the progress in the development of our method for the extraction and manipulation of linear features. In less detail we address the extraction of the topological feature "city-boundary", as the result of texture-based area segmentation.

LINEAR FEATURE EXTRACTION

Out of the wide variety of linear-feature enhancement and detection methods, two are being incorporated into our process:

1. GOP - LINE and LINECONS

    The standard Image Processing Software on a ContextVision GOP system contains a line-detector called LINE. By comparing the convolution-results of a subimage with a set of (both line- and edge-"detecting") 15 * 15 kernels, it evaluates the hypothesis of a linear feature passing through (the center of) the subimage.

The result consist of a measure of certainty for the validity of the hypothesis, as well as an indication for the orientation of the line (if there is one). These two together are used as input for the operation LINECONS, during which the consistency of the LINE-result is evaluated, again by taking large subimages into account. As a result, gaps in lines are filled and noise is removed.

One advantage of the approach is that the orientation of the detected lines can later be used for "object description". It represents a local line-characteristic, since it is not necessarily constant over a (curved) linear feature.

2. Original-minus-median

Subtraction of the result of a median operator from the original image results in an image in which the non-zero elements indicate thin lines or small objects (noise?) in the original. "Thin" and "small" are related to the size of the subimages used during the median operator.

LINEAR OBJECTS AND SYMBOL IMAGES

After thresholding a "linear feature image" a binary "linear object image" is obtained. Next, based on the binary values of its 8 neighbours, each object pixel is assigned a "local topology identifier", denoted as a symbol. The following symbols are used:

    p (isolated Point)
    s (Start of line)
    l (Line)
    L (fat Line)
    t (T-junction, a "node" in the line topology)
    x (X-crossing, a "node" with four "arcs")
    e (Edge of a larger object)
    b (Body, inside a larger object)

A pixel that is assigned L (fat line) is recognised as being part of a linear structure, but it does not contribute to the line-topology: after such a pixel is removed from the set of object pixels, the same (thinned) line remains.

Having the "hardware" capability of transforming the 9 bits in a binary 3*3 neighbourhood into an index in a look-up table, the ContextVision BOP (Binary Operator Processor) is an excellent tool for generating these symbolic images. Processing time for a 512*512 image is 0.6 s.

Since each object pixel in a symbol image contains information about its neighbourhood, other non-linear filters and logical operators (using the BOP) on symbol images can be used to measure and improve consistency. Operations like: small object

(again: noise?) removal, gap filling and selective object shrinking and expansion become straightforward. Before effectuation of these changes (of the objects), it is possible to pass the change-information back to the lower level, in order to check whether a local threshold adaptation could also have affected the objects in the same way.

MULTIPLE RESOLUTION

The (seemingly disadvantageous) property of the Original-minus-Median method of being only able to detect thin lines can be overcome by resampling the image to lower resolutions. It is then possible to distinguish between thin lines (that are detected at the highest resolution) and wider lines (detected at lower resolutions).

At all resolution-levels symbol generation and topology-consistency operations can be performed. After re-resampling to the original resolution, a series of logical and thinning operations is applied to obtain one object image.

The logical operations can take an order of priority into account in case symbols generated at different resolutions coincide spatially and conflict logically. Since we are looking for linear features, symbols from the line-topology set (s, l, t, x) have precedence over area-related symbols (e and b) and over points (p).

By keeping track of the resolution at which each object pixel in the final image was generated, it is possible to attach a (local) property "estimated line-width" to object pixels.

Under the assumption that a linear topological object has a constant width, the line-width distribution over an object might serve as a further consistency measure.

CITY BOUNDARIES

During spectral classification the class "city" often appears as a mixture of other classes (bare soil, roads, grassland, trees etc.), that means without a clear spectral signature.

However, cities do have a "textural signature", as they consist of (more of less) regular repetitions of patterns (the road network, house blocks etc.). In order to obtain an area segmentation, the problem is to define and calculate spatial features which are relatively constant over an area of constant texture.

We describe two slightly different approaches, which both use the above-mentioned symbol images as an intermediate result.

The first starts with applying a line- and/or edge-detector, which should be chosen in accordance with the resolution: it must detect the "objects" (or object boundaries) within cities. Next a threshold is applied and from the resulting binary image, a symbol image is generated.

The second approach generates a symbol image from the original image immediately: In each 3*3 subimage the 8 neighbours are compared to the central element and, using a threshold, assigned "similar" (1) or "different" (0), the central pixel itself being 1. The obtained binary pattern determines a symbol. So to every element a symbol is assigned.

Now, in both cases, texture is characterised by density of each symbol (topology class). Within an area with a homogeneous texture, each symbol class has a uniform density (number of symbols per area unit). Feature selection is based on the selection of the symbol classes with most distinct densities over a training set.

For density calculation we are currently investigating the usefulness of the so-called "distance-transform", which, amongst others, is known from GIS buffering applications. The distance transform assigns to each non-object pixel in a binary image the distance to the nearest object pixel. Again, the BOP allows for a very efficient implementation (processing time is proportional to the maximum distance; with a 512*512 image and a maximum distance of 64 pixels the operation takes about 10 s).

After selecting and combining the most discriminant symbol classes, the distance transform is applied, followed by an average operator. The resulting "average distance to the nearest symbol" image discriminates between different densities (and thus: textures).

The classification is based on this symbol density feature, resulting in a segmented image where segment boundaries delineate areas of constant texture such as found in cities and villages.

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