Morphological Image Sketch Coding

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Abstract

This paper presents a feature decomposition and description algorithm for grey-level images. This algorithm is decomposed into several steps, the first one performs a contour detection, the second one builds objects from these contours. The features are then described by a skeletonization algorithm based on morphological techniques. In this part of the desciption new morphological operators are used in order to have a better compactness of the code. This code can therafter be entropy-coded and leads to a high level compression of the information.

1 Introduction

Classical decorrelation methods based on statistical properties of the signal (DCT, subband coding, ...) have demonstrated great possibilities in the field of image compression. These methods mainly use the fact that the spectral components of the signal are decorrelated. However another possibility to decorrelate the signal is the use of basis functions in the spatial domain that will lead to a non-linear decomposition of the signal. The images can be considered as made up of regions in which properties as texture, intensity are quite constant. These regions can then be considered as composed of non-linear combinations of several primary shapes. The shapes also called structuring elements are the basis functions used to decompose and describe in a compact way the regions of the image.

The aim of this paper is to present a complete algorithm of object-based coding in order to achieve image compression. This will be done in four steps. The first and second ones perform features extraction from the grey-level image. Thereafter, the region decomposition of the image is transcripted into a skeleton by new morphological operators. They have been introduced in order to improve the compactness of the code without affecting the visual perception of the objects. The last step is the entropy-coding of the skeleton that will lead to a compression of the information.

2 Feature extraction

The first step of the processing achieves the feature extraction from the grey-level image. First we use a contour detection based on isotropic energy functions. It has been showed that, at the location of edges in an image, the phase congruency of the Fourier series of the luminance is maximal. A way to calculate this phase congruency is the use of energy functions [1]. The energy function is defined in the following way:

$$E(x) = F(x) + jH(x)$$

where $F(x)$ is the luminance along a line in the image and $H(x)$ is the Hilbert transform of the luminance function.

We just have to evaluate the energy function and maxima will lead to contour points. It can be demonstrated that such an edge detector satisfies some interesting properties as idempotence, insensivity to global DC shift and insentivity to white noise [1].

In order to obtain the various regions of the image, the contours need to be closed. This is achieved by performing a region growing within the edges. The technique is based on successive openings by structuring elements. We perform the following operations:

- Given a structuring element, we fist search for the maximal element , $n_{max}B$, for which the intersection with the contour points is empty. Let X, being the binary image with ones at the location of contour points.

$$n_{max} = \max\{n \in \mathrm{N} \mid (X \circ nB \neq \emptyset)\}$$

- Then, for $n = n_{max} \rightarrow 0$ we add some structuring elements nB to the previous ones according to a specific procedure.

This technique is similar to the blowing of a balloons inside the contours.

After these operations we have decomposed the image into regions in which properties are nearly constant. These regions need then to be described in terms of simple elements, that is what will be done in the next section.

3 Region description

3.1 skeletonization

Any feature in a binary image can be described by the use of morphological techniques. The regions obtained from the grey-level image can be considered as binary objects and decomposed using a skeletonization method [2]. This algorithm allows objects to be decomposed into a sequence of subsets containing growing elements.

Let X be the object to be described. The classical morphological skeleton is calculated in the following way:

The skeleton S is composed of subsets $S(n), n = 0, \ldots, N$.

$$\begin{aligned} S(n) &= (X \ominus A(n)) - ((X \ominus A(n)) \ominus B(n) \oplus B(n)) \\ &= (X \ominus A(n)) - ((X \ominus A(n)) \circ B(n)) \end{aligned}$$

Where $A(n)$ is the structuring element at step n.

$$A(n) = A(n-1) \oplus B(n)$$

$$A(0) = (0,0) \text{ and } (0,0) \in B(n)\, \forall n.$$

We note that if $B(n) = B$ forall n then the skeleton can be written as:

$$S(n) = (X \ominus nB) - ((X \ominus (n+1)B) \oplus B)$$

$$\text{where } nB = \underbrace{B + \ldots + B}_{\text{n times}}.$$

If we write M_n for $X \ominus nB$, we will finaly have:

$$S(n) = M_n - (M_{n+1} \oplus B(n)).$$

This skeleton description will lead to a perfect reconstruction of the initial object by the use of the following relationship:

$$X = \bigcup_{i=0}^{N} S(i) \oplus A(i)$$

and if $A(i) = iB$,

$$X = \bigcup_{i=0}^{N} S(i) \oplus iB.$$

By using this description algorithm, small details whose shape is not correlated with the shape of structuring elements will ask lot of information to be described. In order to avoid this we have introduced new morphological operators that are defined in the next subsection.

3.2 Partial Morphological Operators

Two new morphological operators are now introduced which are generalization of erosion and dilation operators. We will still have the duality relationship between these two. The first we define is the *partial erosion*, a point of the plane will belong to partial erosion of an object X by B if it translates B *nearly* within X, the definition we will use is the following:

$$X \overset{m}{\ominus} B = \{x \in \mathcal{E} \mid \#(X \cap B_x) \geq \#B + 1 - m\},$$

where B_x denotes the translation of B by x. This operation is a generalization of the erosion which is a particular case for $m = 1$. In the same way, we can define *partial dilation* as follow:

$$X \overset{m}{\oplus} B = \{x \in \mathcal{E} \mid \#(X \cap \check{B}_x) \geq m\},$$

where $\check{B} = \{x \in \mathcal{E} \mid -x \in B\}$. Again this operation is the generalization of the dilation which is obtained for $m = 1$. The duality relationship between erosion and dilation still holds with partial operators and is expressed as below.

$$X \overset{m}{\ominus} B = X \overset{n}{\oplus} \check{B},\ n = \#B + 1 - m.$$

These operators can be combined to form morphological filters. We will use partial erosion in the skeletonization algorithm in order to remove small unsignificant details and doing so improve the compactness of the description.

3.3 Skeletonization and Partial Operators

In the calcul of the skeleton, we have defined the sets M_n. These are successive erosions of the initial object by a structuring element B. The erosions can be replaced by partial erosions in the M_n. We obtain then the following relationships:

$$\begin{aligned} M_0 &= X \\ M_i &= (M_{i-1} \overset{m_i}{\ominus} iB)) \end{aligned}$$

The skeleton is calculated in the same way as we have done before.

$$S(n) = M_n - ((M_{n+1} \oplus B(n) \cap M_n)$$

and the object is reconstructed using the same expression as we have seen.

$$X' = \bigcup_{i=0}^{N} S(i) \oplus iB.$$

The parameters m_i used to evaluate M_i allows to make a compromize between the loss of accuracy in the description of the shape and a compact description. The skeleton no more allows a lossless description of the shapes (unless $m_i = 1$ forall i), the reconstructed object X' will always be bigger than X but we can control this loss of accuracy through the parameters m_i. In the shape X' the contours will be smoother than in X.

4 Entropy Coding

The skeleton $S(i)$ of the image can be viewed as a set of triples $(\overline{X}, i, l)$ where

- $\overline{X}$ gives the structuring elements positions,
- i gives their size,
- and l gives the corresponding region or its gray-level.

As it can be seen on Figure 1, the skeleton is made up of strings having very close i and l values. The entropy coding is therefore performed into two steps : first, string grouping and description of the triples by giving the first in absolute values and the other by run-lengths; secondly, entropy coding of the run-lengths.

References

[1] M. Kisworo, S. Venkatesh, G. West, *Modeling Edges at Subpixel Accuracy using Local Energy Approach*, School of Computing Science, Curtin University of Technology, Western Australia, 1991.

[2] J. Goutsias and D. Schonfeld, *Morphological Representation of Discrete and Binary Images*, IEEE Trans. on Signal Processing, Vol. 39, No. 6, June 1991, pp.1369-1379.

[3] B. Simon, *Mathematical Morphology Applied to Objects Oriented Image Coding (in french)*, Master Thesis, Université Catholique de Louvain, Louvain-La-Neuve, June 1992.

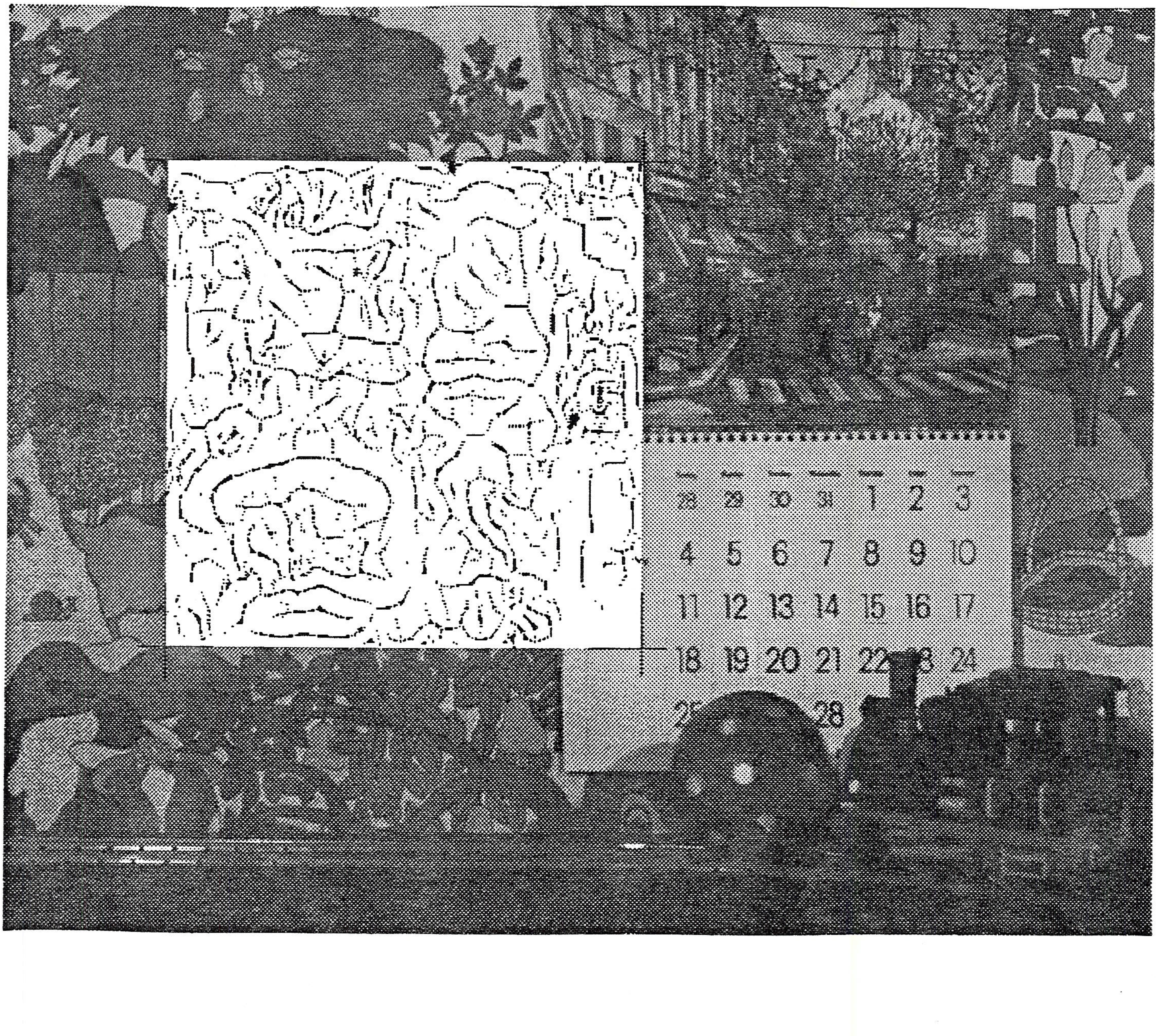

Figure 1: MOBCAL skeleton

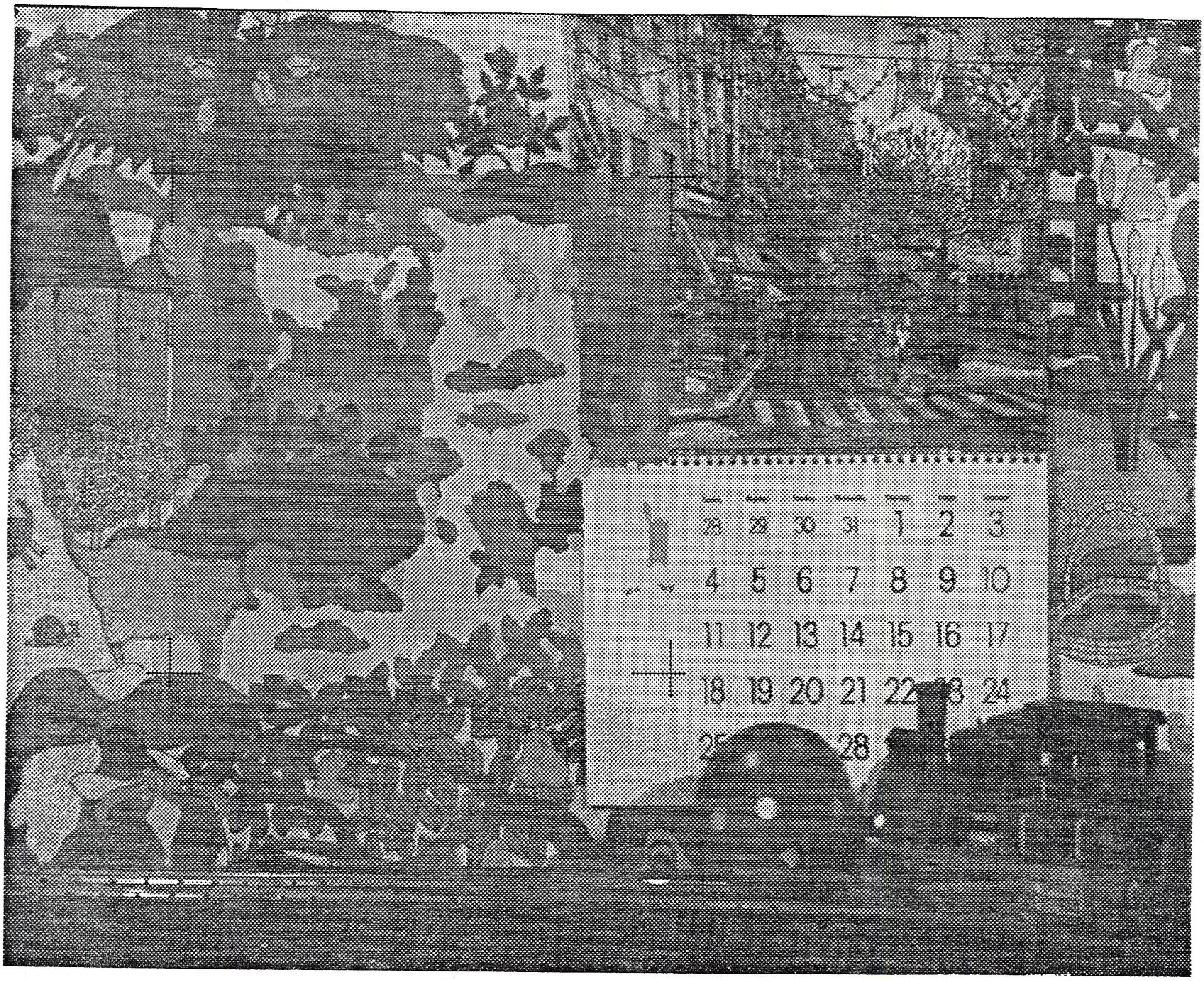

Figure 2: MOBCAL sketch