Postal Envelope Segmentation by 2-D Histogram Clustering through Watershed Transform

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Abstract

In this paper we present a new postal envelope segmentation method based on 2-D histogram clustering and watershed transform. Segmentation task consists in detecting the modes associated with homogeneous regions in envelope images such as handwritten address block, postmarks, stamps and background. The homogeneous modes in 2-D histogram are segmented through the morphological watershed transform. Our approach is applied to complex Brazilian postal envelopes. Very little a priori knowledge of the envelope images is required. The advantages of this approach will be described and illustrated with tests carried out on 300 different images where there are no fixed position for the handwritten address block, postmarks and stamps.

1. Introduction

It is well known that the proper addressing allows mail pieces to be processed quickly and more efficiently. We also know that this task is not a mystery. When the mail piece meets size requirements, address block and zip code are filled in correctly and the proper amount of postage is obeyed, it moves easily through the mechanized sorting process saving labor and time.

Therefore, despite of all rules mentioned above, why is so difficult to increase mail sorting automation? Some reasons like wide variety of postal envelope attributes (layouts, colors and texture), the handwritten address block which appears mixed up with postmarks or stamps difficult an efficient mail sorting system. One of the greatest challenges to improve the postal service is solving the problem of automatic location of address blocks in envelope images. This segmentation challenge involves partitioning into several semantic clusters the envelopes which can contain text and graphic messages in addition to the address block, postmarks and stamps. To complicate the problem further, there are no fixed positions for these items. Hence, the correct address block location is highly dependent of the correct location of another items. By segmenting not only the handwritten address block, but also postmarks, stamps and background one can solve some problems.

The goal of this paper is to propose a new postal envelope segmentation method, based on 2-D histogram clustering, concerned in locating and segmenting handwritten address block, postmarks, stamps and background with no *a priori* knowledge of the envelope images. A new definition of 2-D histogram based on morphological grayscale dual reconstruction will be proposed. The 2-D histogram clustering will be carried out by means of the morphological watershed transform.

This paper is organized as follows: section 2 will shortly review histogram-based techniques to solve the segmentation challenge. The new 2-D histogram will be presented in section 3, section 4 will detail the proposed method. Section 5.1 will present some tests and results carried out followed by the evaluation of the proposed method in section 5.2. Finally, some conclusions are drawn in section 6.

2. Histogram-based techniques for segmentation challenge

Histogram-based techniques assume that homogeneous classes group themselves "naturally" as clusters in an appropriate space. The advantage of this type of techniques is that they do not need *a priori* knowledge.

We can find histogram-based segmentation algorithms in the literature. Lim and Lee [7], Liu and Yang [8] proposed an approach to segment color images based on decomposition of 1-D color histograms into the sum of Gaussian distributions. Celenk [4] proposed another approach based on 1-D color histogram in 3-D clustering. The main problem is that all theses techniques suffer from the lack of local spatial knowledge.

An effective way to overcome this problem is to employ

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2-D histogram which allows not only grouping objects of an image in clusters but also preserving the local spatial knowledge. The notion of 2-D histogram is mainly used to image thresholding, where it is computed by two images: the original one and a filtered one, usually obtained by an average filter as proposed by [1], [3], [12] and [6]. However, in our case, processing the 2-D histogram with the original image and averaged one has the drawback of introducing new gray levels that do not exist in the original image, which can lead to some distortions in terms of segmentation. A new definition of 2-D histogram based on morphological reconstruction will be further proposed.

The detection of clusters in a 2-D histogram is not a trivial task, once it is necessary to assist the gray level occurrences, which is computationally expensive. In the literature, there are some approaches which deal with histogram clustering. One of them is the morphological watershed transform which is able to overcome noisy and heterogeneity problems that occur in postal envelope images. It is not rare to find in postal envelope images noise, complex (and creased) background and inhomogeneous handwritten address blocks.

Shafarenko *et. al* [10] presented a segmentation algorithm for color images that uses the watershed transform to segment either the two-dimensional (2-D) or the three dimensional (3-D) color histogram of an image. This method takes place in a perceptually uniform color space (in this case the *Luv* space). The 2-D histogram is constructed by summing up votes for all intensities occurring at each point of the plane *uv*. To avoid oversegmentation usually inherent to watershed algorithm the histogram is smoothed.

Luo *et. al* [9] proposed an approach to detect abnormality in color fundus images, which is performed on the object-based color difference image. In the color difference image, bright and dark objects are highlighted through *Luv* or *Lab* color spaces respectively. To suppress undesired background and minor objects which are sensitive to the watershed transform, the authors apply a pre-thresholding and also a post-verification to erase obscure candidates, blood vessels and optic disk.

3. 2-D Histogram based on morphological grayscale dual reconstruction

Consider a digitized image $F = [f(x,y)]_{M \times N}$ of size $(M \times N)$ with $[0,..,L-1]$ gray levels, where $f(x,y)$ is the gray level of the pixel at location *(x,y)*. Consider also a filtered image $G = [g(x,y)]_{M \times N}$, where $g(x,y)$ is the gray level of the pixel at the location *(x,y)*. The 2-D histogram of images *F* and *G*, is a $L \times L$ dimensional matrix $C = [c_{ij}]_{L \times L}$ which contains some statistical information regarding the number of gray level occurrences of two pixels at the same location *(x,y)*. The 2-D histogram $C = [c_{ij}]_{L \times L}$ from any pair of pixels $f(x,y)$ and $g(x,y)$ having respectively the gray levels *(i,j)* can be formalized as follows:

$$c_{ij} = Card\{(f(x,y), g(x,y)) / \ f(x,y) = i, g(x,y) = j\} \quad (1)$$

where *Card* denotes cardinality.

The 2-D histogram is highly dependent of the correct choice of the second image. As already mentioned, such image is usually obtained by an average filter [1], [3], [12] and [6], which can introduce, in the filtered image, non-existent gray levels in the original image. To overcome this problem, we have used a morphological filter. Among all morphological operators (see [5] for more details), the morphological grayscale dual reconstruction (see [11]) has the advantage of preserving peaks and modifying valleys (Fig 1). This is a crucial point if we want to preserve without spreading the noisy and complex (usually creased) background and modifiying the handwriting address block, postmarks and stamps information (which looks like grayscale valleys).

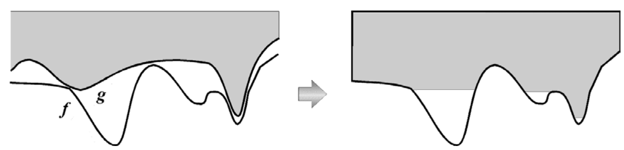

Figure 1. Grayscale dual reconstruction of mask f from marker g

In the particular case of postal envelopes, most of homogeneous regions remain identical by grayscale dual reconstruction. Basically, these unchanged regions represent the background which is a great region, if compared to another classes. Consequently, a huge number of occurrences, corresponding to the background, lie on the principal diagonal of the 2-D histogram. The drawback of this process is the distortion caused by the clustering process. To reduce the influence of these unchanged regions and to equalize the importance of the searched classes, the 2-D histogram diagonal is set to 0.

4. Clustering

We are aiming at automatic clustering, where all classes should be extracted from the image through the 2-D histogram. Ideally, these classes are the handwritten address block, postmarks, stamps and background. To do that, we have used the morphological watershed transform. To better understand it, one can see the 2-D histogram as being

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a topographic relief, where the highest areas correspond to peaks, while the lowest ones would be the valleys. If a drop of water is placed on any point of that relief, it will slide until it rests on a place we will call the local minimum (see [2] for more details). The cluster of all those points where the drop of water finally rests in a given region with a minimum M is defined as being the watershed area $W(M)$, associated with the minimum M (Fig 2). The meeting point of two watershed areas generates a border forming the watershed line, which is the outcome of the watershed transformation process [2].

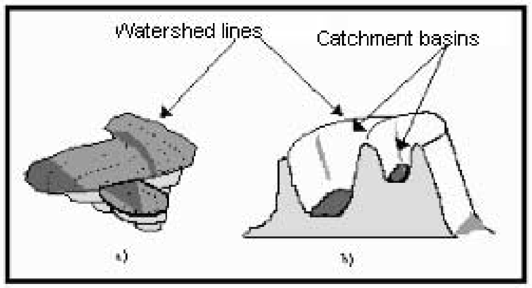

Figure 2. Watershed lines and Catchment basins

To efficiently segment the 2-D histogram by watershed transform, it is required that the markers are located in the local minima where they will be pierced. We have used the morphological grayscale dual reconstruction where the mask correspond to the 2-D histogram itself and the marker correspond to the 2-D histogram plus one occurrence (2-D histogram + 1) to locate these local minima. This process guarantees the exact location of the only true minima.

5. Experimental results

5.1. Segmentation results

The proposed approach has been evaluated on 300 Brazilian postal envelopes with no fixed position for the handwritten address blocks, postmarks and stamps. The images were randomly chosen. This complexity is reflected over the 2-D histogram which presented a huge number of basins (over 25). Then, a post-processing step was necessary to decrease the number of basins and consequently markers. For this task, we used the morphological erosion which allows to join flat basins without loss of information and to join flat basins with deep basins without increase the depth of the same ones. Hence, the system processes *n* erosions until it is possible to obtain the number of expected markers (*i.e.* expected classes) through the morphological reconstruction, which are required by the morphological watershed. This post-processing step is totally automatic without training tests.

5.2. Evaluation of the proposed method

Due to the similarity of the thickness and the gray levels between handwritten address blocks and postmarks, we perceived that we handwritten address blocks and postmarks are always segmented together. Them we propose to segment the envelope images into three classes:

1. Stamps;

2. Handwritten address block and postmarks;

3. Background.

To evaluate the efficiency of the proposed approach, for each envelope image, we have generated the ideal solution (ground-truth segmentation). Hence, we have computed each obtained result with the ideal segmentation in terms of identical pixels at the same location. We also have computed the average of all obtained results for each class (handwritten address block and postmarks, background and stamps) which are showed in Table 1. From the Figure 3-(a), which shows a complex postal envelope with creased background, irregular handwritten address block and inhomogeneous classes such as postmarks and stamps. It is possible to observe that the proposed method has detected three classes as expected which are depicted in Figures 3-(d) to 3-(g). However, one can see that the classification rate regarding the stamps was not good. It is caused by the fact that the stamps are the smallest part in an envelope image which means that any small change in the obtained segmentation (Figure 3-(g)) if compared to the ground-truth segmentation (Figure 3-(c)) can prejudice this rate. Another cause is the complexity usually inherent to Brazilian stamps, which contain some complex drawings, gray level differences (dark objects and bright background) difficulting a good rate.

Class	Rate
Stamps	25%
Handwritten Address Block and Postmarks	75%
Background	90%

Table 1. Average segmentation rates for each class.

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6. Conclusions

A new postal envelope segmentation method combining 2-D histogram and morphological clustering by watershed transform concepts were proposed. A new definition of 2-D histogram based on morphological reconstruction was proposed. Unlike the previous clustering techniques which carry out the partition based on distance measure, the proposed clustering was based on the watershed transform criterium. The proposed method was shown to be efficient and encouraging in segmenting and isolating the handwritten address block, postmarks, stamps and background classes on complex Brazilian postal envelopes where there is no *a priori* knowledge about the position of the handwritten address block, postmarks and stamps. By comparing the obtained results with the ideal ones (ground-truth segmentation), one is able to see that the proposed approach is robust if we consider the *handwritten address block and postmarks* and *background* classes. Consequently, this method can be employed to segment another types of document images.

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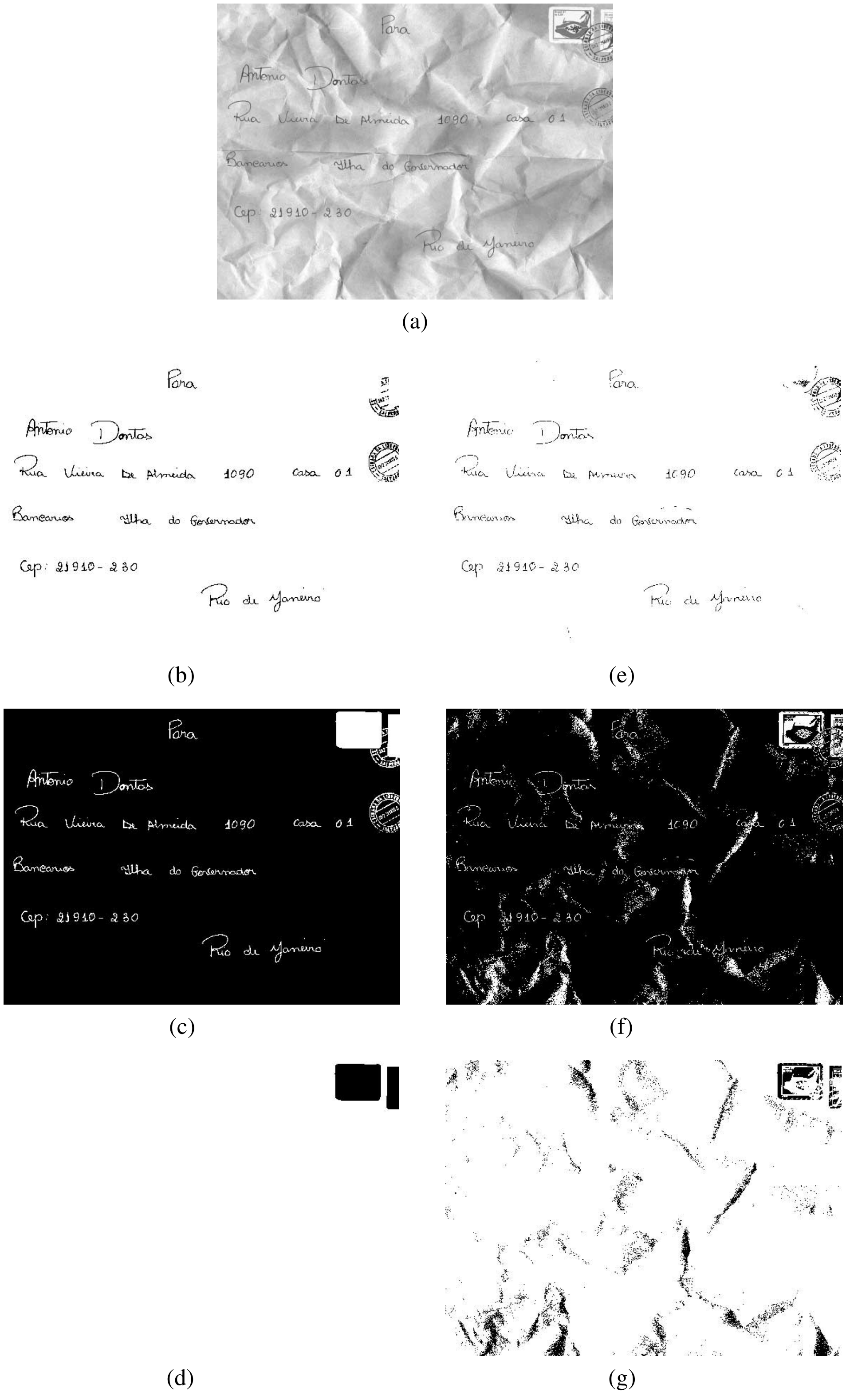

Figure 3. Results of the proposed approach compared with ground-truth segmentation: (a) Envelope image with creased background, (b)-(d) Ground-Truth segmentation, (e)-(g) Segmentation results.