Extracting written lines from cheques

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Abstract

We present a method to extract written lines from complex backgrounds of cheques. The method is based on a local measure which gets positive values for ideal dark written lines, a null value for ideal edges and negative values for white ideal written lines. The distribution of the gray level according to this local measure is contained in a diamond ODUW that can be divided in three important regions : ideal written lines, uniform regions in the image, ideal dark written lines. A synthetic image is used to show that any discriminating function must cross point O of the diamond. A global process searchs for a linear discriminating function to separate the region of dark written lines from the uniform region. A first evaluation on 120 cheques with 16 different complex backgrounds gives 92% of correct results. 8% contains remaining background. This method is an improvement of the previous one [15].

1. Introduction

Extracting handwritten information correctly from background images is the first step of a more global process including the recognition and interpretation of all items on the cheque image such as the amount, the date, the owner, etc. [1][2]. This first step may have various degrees of complexity depending on the nature of the background image. When the background is uniform, the histogram contains two modes, which can be separated by identifying the minimum between them. Global thresholding is then suitable and it is still used in many character recognition systems. For non uniform backgrounds, as where the document has a graduated illumination, researchers have investigated many other types of threshloding: adaptive, dynamic and local thersholding [3] [4] [6]. This problem is addressed in many fields of document analysis : as address extraction from postal packages, OCR, and cheques processing. With more complex backgrounds, as in the presence of a picture on a cheque (or on another document), researchers use other techniques such as morphological approaches [5], or making a subtraction directly between a virgin model of a cheque and a real specimen [7][8]. In some special cases, when a certain hypothesis can be made on the background, as the presence of a gaussian noise or a periodic structure, the extraction is generally successful [9][10].

In general cases, when no hypothesis can be made on the background image, the problem can be expressed as follows : what operator can respond only to lines present in the image? Standard edge detectors, will respond to any line present, including handwritten lines but also contours. The problem therefore, is still complicated because we have to eliminate contour lines from the resulting image. This cannot be done without some hypotheses on the background structure.

On the opposite, it's very easy for the human eye to perform this task. The experimental study on psychovisual tests conducted by Burr and al. [11] confirms the idea suggested previously [12] [13], that the detectors of the human visual system take advantage of the even symmetry that characterizes a written line and of the odd symmetry that characterizes a contour line. By written lines, we mean lines which can be handwritten, printed or graphic lines, and by contour lines, we mean the frontier of regions. In a previous work [14] we have presented a simple measure which gets positive values for dark written lines. In another work [15], we used this difference between of written lines and contour lines to define a topological criterion specific to written lines in binary images and extended it as a 'filiformity' measure for gray scale images. A global process then, compared this measure to a threshold and decided if a pixel belonged to a written line or to the background. The evaluation of this technique proved to be efficient most cases. The principal drawback was the remaining pixels belonging to graphic lines composing the background. Attempting to use a high threshold value produced generally damaged written lines.

In this paper we present a new decision process which takes into account the 'filiformity' measure and the gray scale level in the goal to reduce the remaining background pixels without damaging written lines. In section 2, we present an extended filiformity measure. The first measure, as given in [15], takes a null value for bright ideal written lines. The extended measure can take into account either a dark or a bright ideal written line. We study the distribution of the gray scale level according to the extended measure. The interpretation of this distribution reveals three different regions with useful signification in the image : ideal white written lines, uniform region and ideal dark written lines. In section 3, a global process is presented in the goal to separate the region of interest : the region of dark written lines. The algorithm searches for a linear discriminating function. The use of a synthetic image suggests that any discriminating function must pass over the origin. In section 4, we make a first evaluation of this technique on 120 cheques with 16 different backgrounds and show why we consider this global process more powerful than the first one proposed in [15]. In 92% of the cases, the results were correct and we explain why the remaining 8% were not.

2. A written line measure : $\mu(p)$

If we look at the image as 3D surface, dark written lines seem to be trenches and the deepness of these trenches is related to the darkness of the line. Let $\eta(p)$ be the gray scale level of a pixel p, $\eta(p) \in [g_{min}, g_{max}]$, where g_{min} and g_{max} are the minimum and the maximum respectively of the gray scale level. Two parameters are necessary to describe a trench : the width and the deepness. Consider a straight line D passing over the pixel p, it defines two segments s_1 and s_2 around the pixel p as shown in figure 1.

A typical filiformity measure can be expressed as follow [15] :

$$\mu(p) = \underset{D}{\mathrm{Max}}\left\{\min(\eta(s_1), \eta(s_2)) - \eta(p)\right\} \qquad (1)$$

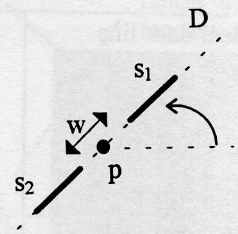


Fig. 1 The μ measure.

The μ measure is the maximum of $[\min(\eta(s_1),\eta(s_2)) - \eta(p)]$ over all directions D around p.

Where $\min(\eta(s_k))$ is the smallest gray level of pixels belonging to segment s_k.

As shown in table 1, $\mu(p)$ gets positive values only for pixels belonging to ideal dark written lines.

For other situations such as ideal white written lines, ideal edges or uniform region, $\mu(p)$ gets a null value. However, $\mu(p)$ can get negative values only for isolated bright pixels, or small bright regions with a width less than 2*w. To make the measure responding symmetrically for either a dark line or a bright line, but with opposite sign, we extend $\mu(p)$ to the following form :

$$\mu^*(p) = \begin{cases} \mu_1(p) & \text{if } |\mu_1(p)| \geq |\mu_2(p)| \\ -\mu_2(p) & \text{else.} \end{cases} \qquad (2)$$

where $\mu_1(p)$ is the measure defined by equation (1), $\mu_2(p)$ is the same measure performed on the inverted image. The inverted image is defined by replacing each level $\eta(p)$ by $g_{max} - \eta(p)$.

We can verify, in table 1, that for an ideal dark written line, $\mu^*(p)$ is positive, becomes negative for ideal bright written lines and gets a null value for ideal edge.

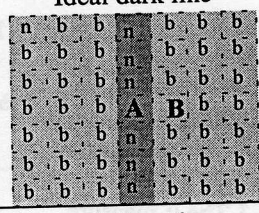
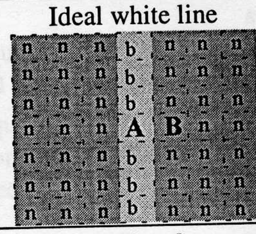
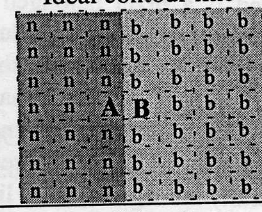
For this fact, we prefer to use μ^* rather than μ, as a local measure because it reflects more precisely the luminance topology of an image.

Because μ^* is a difference of gray levels, we can write : $\mu^*(p) \in [g_{min}-g_{max}, g_{max}-g_{min}]$, and also :

$$\eta(p) + \mu^*(p) \leq g_{max} \quad \text{and} \quad \eta(p) - \mu^*(p) \geq -g_{max}$$

These two inequalities mean that all the pairs $(\eta(p), \mu^*(p))$ must belong to the diamond ODUW as shown in the figure 2. To interpret different positions inside this diamond, we first define idealized written lines that are taken as

Table 1. Difference between μ and μ^*.
w=0, s=1, h is the difference between levels of white and black, $h = \eta(b) - \eta(n)$.

Ideal dark line	Ideal white line	Ideal contour line
		
$\mu(A) = +h$ $\mu(B) = 0$	$\mu(A) = 0$ $\mu(B) = 0$	$\mu(A) = 0$ $\mu(B) = 0$
$\mu^*(A) = +h$ $\mu^*(B) = 0$	$\mu^*(A) = -h$ $\mu^*(B) = 0$	$\mu^*(A) = 0$ $\mu^*(B) = 0$

references to allow the comparison to other lines. Ideal 'best' dark line is defined with g_{min} level written on a region of g_{max} level. Such a line does not suffer of any ambiguity to be 'seen' as a dark line. Their pixels are located at point D of the diamond. The distance to point D, can be considered as a measure of the quality of a given line as compared to the idealized dark line. The region close to point D is then the region of the best dark written lines. Inversely, an ideal white written line is defined as a line with g_{max} level overwritten on a black region with g_{min} level. Their pixels are located at point W. The region close to point W, is the region of the 'best' white lines. The region around the axis η, is the set of points where μ^* has a small absolute value, this fact characterizes generally uniform region. Finally, we retain three regions of ODUW which decompose an image in three parts : bright lines, uniform regions and dark lines.

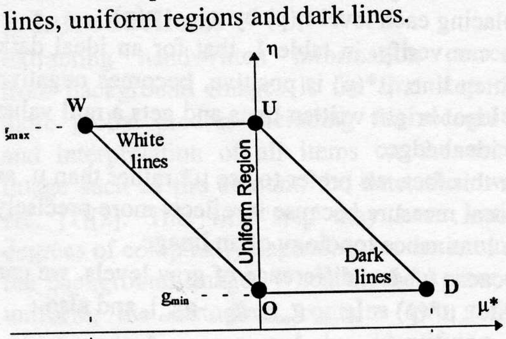


Fig. 2 The diamond ODUW and its different regions of interest.

3- Global Processing

The task of the global processing is to find a discriminating function which delimits the region of dark lines. Real written lines have gray level which may vary for example with the speed and pressure of pen during writing [1]. The line's pixels then can occupy a wide zone on the right side of the diamond. To analyze this fact, we synthesized a particular image, see figure 3 (the last pages). The image contains non uniform background, two dark lines and a white line. The background is synthesized such that the gray level increases linearly from left to right. The first dark line is synthesized such that $\mu^*(p)$ increases by step from left to right while the gray scale is maintained between two values $\eta 1$ and $\eta 2$. This variation may occur for real written lines, when pressure and speed vary lightly, so $\eta 1 < \eta < \eta 2$, but the lines overpass different regions of background, so μ^* may vary highly. The second dark line is synthesized such as both η and μ^* increase linearly together from left to right. This kind of variations, is for written line where speed and pressure of pen vary greatly. The white line, is maintained at gmax level.

The distribution (η, μ^*) of this image highlights different regions as expected in the interpretation above. Many points of the distribution are superimposed. The white line is in the region near W. The two dark lines are in the region near point D. The region around the axis U, is for the background. However if we take all points with positive μ^*, we find not only the two dark lines but also dark lines around the white lines. Inversely, if we take all points with negative value we get white lines around the dark lines. This 'factious' lines have small deepness, small absolute value of μ^*, and mimics partly the phenomenon of visual perception known as 'contrast of Mach' [17].

This particular image suggests that the discriminating function must pass near point O and include the set 1 and set 2 in the distribution. Passing over point O, allows detecting lines with small positive value of μ^* when the gray level is also small. This situation occurs when a dark line is written over a dark background, which is the case of the two dark lines in the left of the image. We search for a linear discriminating function defined by point O and a second point S. Starting from point O, the algorithm tries to find the best direction between OU and OD where the density of points is minimum.

A simple way to do this is to project all the points with μ^* positive, on the side UD, and to look for the minimum density, see figure 4. We construct a projective histogram as follow :

For each point P inside the triangle OUD, we compute the projection length of vector UP on segment UD by computing the dot product <UP, UD>. A value indexed by the dot product, is then incremented by one.

The projective histogram is generally a noisy curve and we have to smooth it. The dark line region is expected to appear as a lobe in the right side of the histogram. The value which delimits the right lobe is then taken as point S in segment UD. The points of dark lines region are under the segment OS, this can be described by simples geometric considerations : Let L, be the length of US, then

$$OS = \left\{ \frac{L}{\sqrt{2}},\ g_{max} - g_{min} - \frac{L}{\sqrt{2}} \right\}$$

Let V be the perpendicular vector to OS in counterclockwise,

$$V = \left\{ -g_{max} + g_{min} + \frac{L}{\sqrt{2}},\ \frac{L}{\sqrt{2}} \right\}$$

The points of a dark line must have a negative dot product with V. Let P be a point of the distribution, $OP = (\mu^*(p), \eta(p) - g_{min})$, then $<OP, V> < 0$ which gives the following condition for a point to belong or not to a dark written line.

$$\eta(p) > \left(\frac{\sqrt{2}}{L}(g_{max} - g_{min}) - 1 \right) \mu^*(p) - g_{min}$$

4 Experimentation and evaluation

Once implemented, this algorithm was evaluated on 120 cheques with 16 different complex backgrounds. A complete evaluation with a huge number of cheques and a well defined criteria of quality of the results should be done in the near future. However our experimentation was made

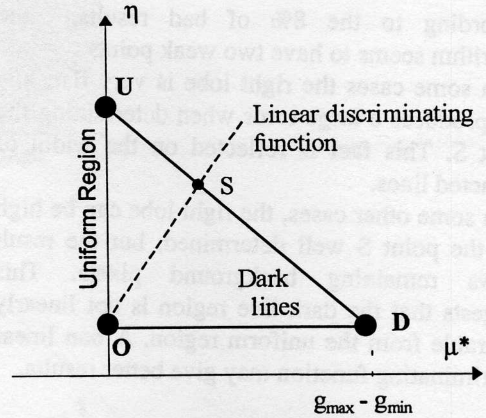


Fig. 4 Determination of dark lines region.

as a first evaluation to adjust some parameters as the size of the median filter to use to have a smoothed curve and to fix the values of w and s in the formula of μ^*. We used a median filter of size three, twice on the projective histogram. We found that w=3 and s=2 give good results for 100 dpi resolution scanned images.

Two simple quality criteria were chosen : remaining background pixels and the damage in written lines.

In 92% of the cases the results showed a complete elimination of the background and no damaged written lines. In 8%, some pixels of the background remain, most of them belonging to real lines composing the background picture. This lack of the algorithm seems to be the same as in our previous method [15], however it differs in two ways, that we have noticed experimentally :

1) When making a small error in estimating the point S, the written lines on dark background are not damaged, although their width can be lightly reduced. With the previous method, this written lines are more sensitive to the error on the threshold, and generally became damaged.

2) Taking a small lobe on the right side of the projective histogram can eliminate, in some cases, the remaining background, although this reduces the width of the written lines. Attempting to use a high threshold in the previous method, damages written lines before eliminating the remaining background.

These two facts are illustrated in figure 5-(d, e, f,-g) where the skier stick could be removed by taking a restricted right lobe in the projective histogram and by taking a high threshold in the previous method.

According to the 8% of bad results, the algorithm seems to have two weak points :

1) In some cases the right lobe is very flat, and this produces a large error when determining the point S. This fact is reflected on the width of extracted lines.

2) In some other cases, the right lobe can be high and the point S well determined, but the result shows remaining background pixels. This suggests that the dark line region is not linearly separable from the uniform region. A non linear discriminating function may give better results.

5 CONCLUSION

We presented a specific measure for idealized written lines. The distribution of the gray level according to this measure is contained in a diamond ODUW which has three significant regions : white written lines region, uniform region, dark written lines region. The global process uses a linear discriminating function to separate the region of interest, dark written lines from uniform regions. The first evaluation made on 120 cheques, shows better results 92% as compared to our previous method [15], although the problematic cases are the same as the one reported with the previous method. 8%, of the cses, the result contain remaining background pixels, which suggests the use of a non linear discriminating function.

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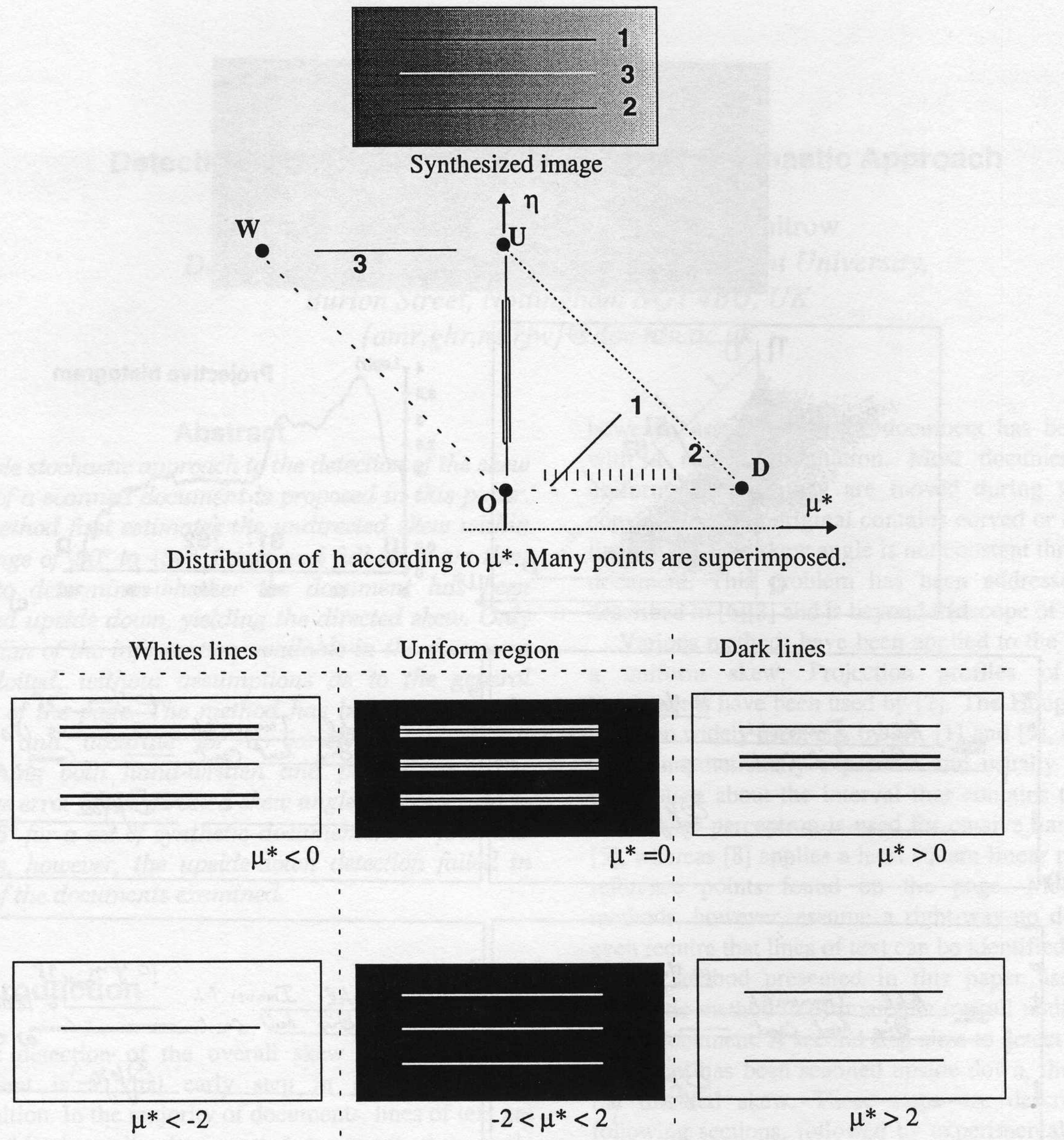

Fig. 3 Distribution of a synthetic image.

Pixels verifying the relation indicated below each result, are black.
Factious white (dark) lines appear around dark (white) line, when we take $\mu^* > 0$ ($\mu^* < 0$), as the contrast of Mach. When comparing to a small threshold, we get correct results for the three cases. This suggest that to extract the two set of dark lines, the discriminant function should pass near point O.

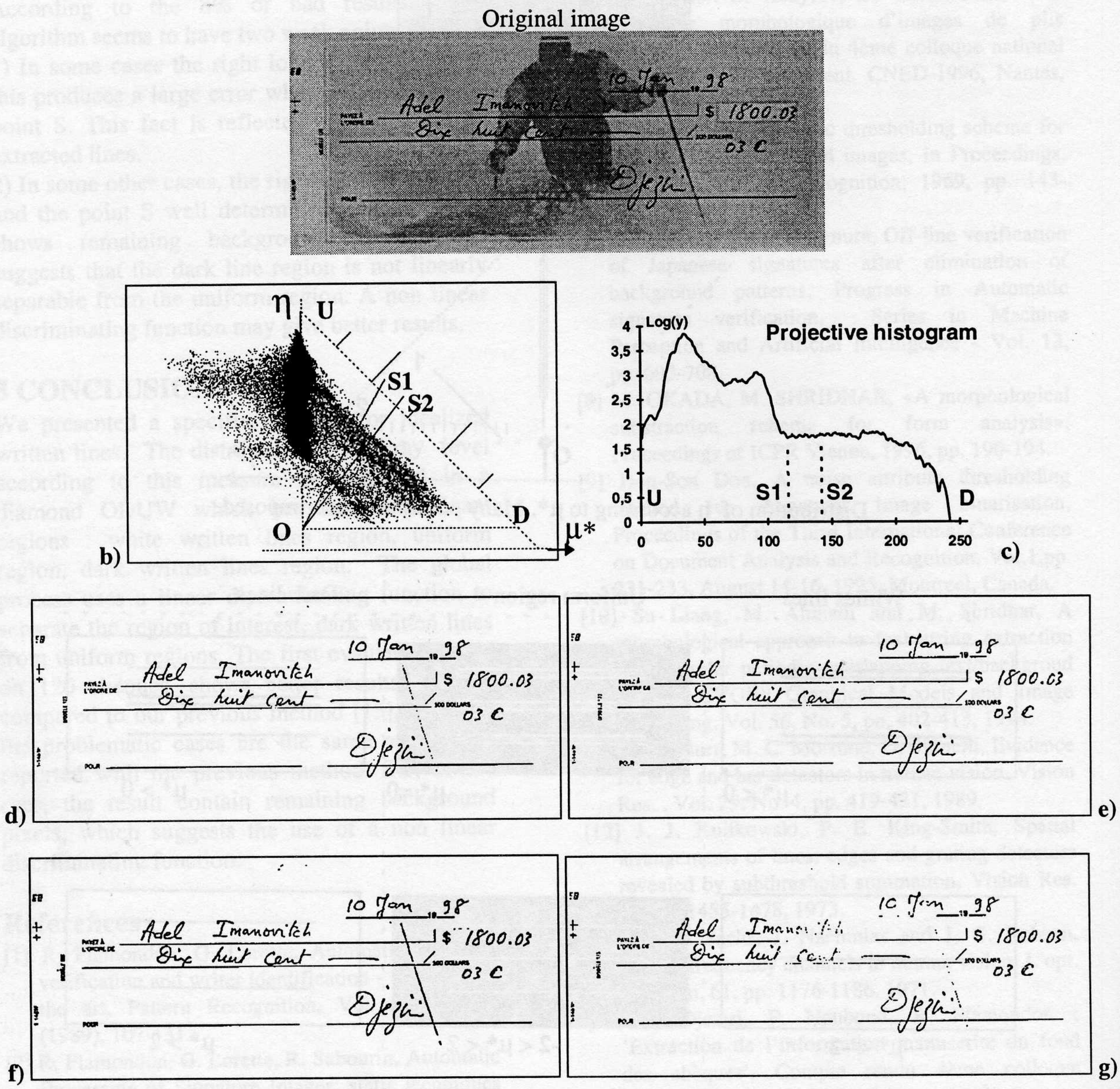

Fig. 5

a) Original image of a check. **b)** Distribution of (η, μ*) of the image. The projection of this distribution over segment UD yields the projective histogram shown in c). The right lobe in the histogram is flat, this can produces an error when estimating the threshold S. This is illustrated by taken two values S1 and S2. This values are reported on segment UD in figure b). **d)** is the result obtained by taking all points inside the triangle OS1D and **e)** by taking all points inside OS2D. The remain background pixels, the stick skier, in d) disappeared in e) with no damage in written lines. The two results have to be compared to **f)** and **g)** which are obtained by our previous method [15]. **f)** is the result by comparing μ to an optimal threshold as described in[15]. **g)** is an attempt to take a greater threshold to eliminate the stick skier. The written line are damaged.