Methodologies to Validate Both, the Photo Printing Type and its Spatial Resolution in Personal ID Documents

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Abstract. This paper introduces two new image-processing methods, the first one determines if the picture appearing on a Personal ID -card is printed in analogical or digital format. The second method determines if the digital photo has a spatial resolution of 800 dots per inch (dpi) . Both methods are tested with the IFE Voting ID-card, which is a "non-official" personal document used as the main identification card in Mexico. Both methodologies were developed by using morphological techniques to extract the useful characteristics by means of a previously defined structure element according to the size on the photo in the document. We tabulated the efficiency of these two methodologies after its use in 30 different ID-cards, 10 out of them analogical and the remainder 20 having digital photograph. All they were genuine ID-cards.

Keywords: Image processing; Photo printing-type; Spatial Resolution; Personal ID documents.

1 Introduction

The Voter Registration Card with photograph is a document issued by the Federal Electoral Institute (IFE-Instituto Federal Electoral), an autonomous agency in Mexico. The Voter Registration Card is used to vote in Federal and State elections in Mexico. In spite of the fact that this is a non-official document, it has become indispensable for Mexicans because it is the only valid ID document issued to adult persons legally that enables them to make bank and money transactions or get access to night clubs and buy cigarettes and alcoholic beverages in the whole country.

There are several locks or security means in the Voter Registration Card with photograph (the "Card") that have been introduced in its design in order to make difficult its forgery [2]. The photograph printed on the Card is an object which has some features incorporated by the IFE to make its forgery almost impossible.

In the Card the photograph may be printed in one of the following two ways:

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Special Issue in Advances in Pattern Recognition
Research in Computing Science 44, 2009, pp. 105-113

analogically, with the photo obtained with a conventional Polaroid camera [3] and digitally, as an image with an 800 dots per inch resolution. In order to confirm the authenticity of the Card, a method to validate the kind of print (analog or digital) and the spatial resolution used to print it in case it was digital, is proposed. The fact that the photo was printed in analogical or digital way depends on the date the ID-card was emitted.

In a state-of-the-art review, it was found that to this date, there is no method to detect the kind of print and to determine the spatial resolution of a digital image.

An analog image can be mathematically represented as a continuous range of values indicating the position and intensity of different objects. The intensity can be represented on a normalized scale from 0 to 1 with infinite divisions, and spatially with an infinite number of two- dimensional coordinates. On the other hand, a digital image is restricted in both its spatial coordinates and in its allowed intensities. Their positions and intensities are represented by finite positive discrete values. The elements that make up a digital image are called picture elements, or pixels.

2 Spatial Resolution

Intuitively, spatial resolution is a measure of the smallest discernible detail in an image. Quantitatively, spatial resolution can be stated in a number of ways, with line pairs per unit distance, and dots (pixels) per unit distance, these being among the most common measures. Suppose that we make a chart with alternating black and white lines, each of W width units (W can be less than 1). The width of a line pair is thus $2W$, and there are $1/2W$ line pairs per distance unit. For example, if the width of a line is 0.1mm, there are 5 line pairs per distance unit (mm). A widely used definition of image resolution is "the largest number of discernible line pairs per distance unit "(e. g., 100 line pairs per mm). "Dots per distance unit" is a measure of image resolution used commonly in the printing and publishing industry. In the U. S., this measure is usually expressed as dot per inch (dpi). To give an idea of the difference in quality, newspapers are printed with a 75 dpi resolution, magazines with 133 dpi, glossy brochures with 175 dpi, and some books with 2400 dpi.

3 Some Basic Morphological Concepts

One of the main applications of the morphological transformations is for removing objects from an image by convolving a preselected structuring element having a given size, shape and orientation and the entire image [7].

Particularly, the top-hat transformation of a gray-scale image f is defined, as the original image f minus its opening (Eq. 1). This transformation allows us to emphasize the clearest zones of the image, so we can get the points where the ink has been printed.

$$T_{hat}(f) = f - (f \circ b) \quad (1)$$

Where $(f \circ b)$ is called the morphological opening.

The opening of a set A by a structuring element B is denoted $A \circ B$ and defined as indicated in Eq.(2):

$$f \circ b = (f \ominus b) \oplus b \quad (2)$$

Thus, the opening A by B is the erosion of A by B, followed by the dilation of the result by the same structuring element B. The erosion is defined as indicated in Eq. (3):

$$[f \ominus b](x,y) = min_{(s,t)\in b}\{f(x+s, y+t)\} \quad (3)$$

On the other hand, the dilation is defined as, Eq. (4):

$$[f \oplus b](x,y) = max_{(s,t)\in b}\{f(x-s, y-t)\} \quad (4)$$

4 Methodologies

During the analysis of the printed photograph it is necessary to take into account the following::

- The kind of print (analog or digital) (Figure 1);
- If the image is digital, the spatial resolution with which it was printed.

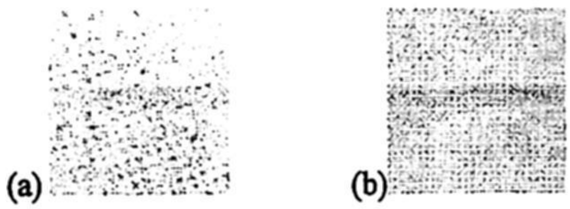

Fig. 1. Kinds of image: (a) digital (b) analog.

In order to find out the kind of print, basic morphological operators were applied to the digital images represented by the photo in the Card. The following flowchart shows the procedure to find out whether the image printed on the Card is analog or digital (Fig. 2).

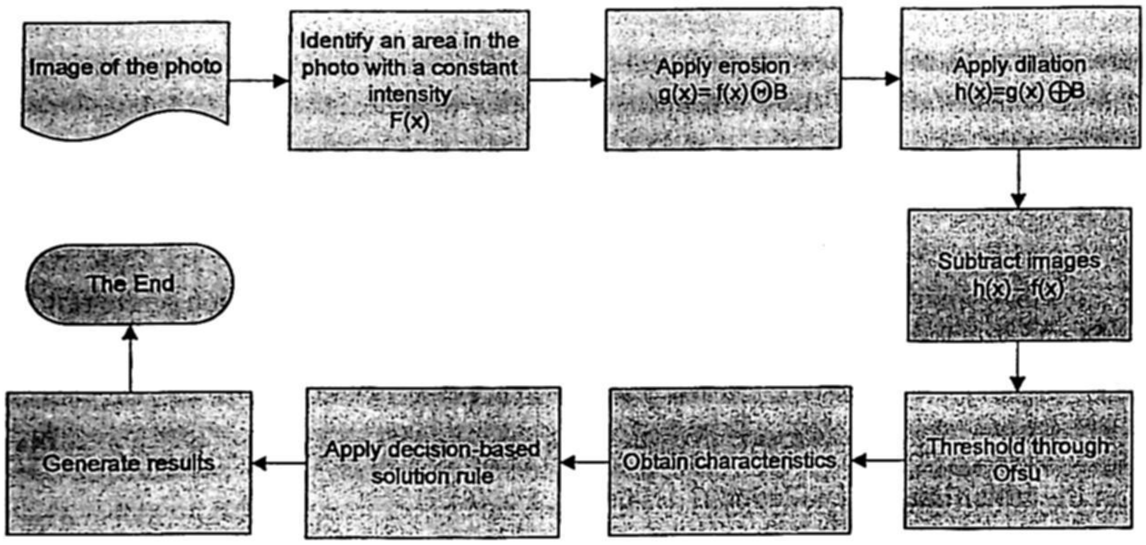

Fig. 2. Flowchart to find out whether the image is analog or digital.

Firstly, a small area with a constant intensity of pale shades is identified in the scanned photo located in the citizen's Card. In our case, 75 x 75 pixels square area was used, equivalent to a 1/16 inch square area in line with the given spatial resolution with which the image was scanned (1200 dpi). An erosion with a 4 x 4 pixels square structure element is applied to this small square area with a reference point at the center; then the resulting image is dilated with the same structure element; finally the resulting image is subtracted from the original image and thresholded by the Otsu method [6]. Once the final image is obtained, the following features are checked:

- If the dots are homogeneous in size;
- If the printed dots appear to be continuous.

Checking that the dots are homogeneous in size is achieved by enclosing a part of the image within an imaginary circle smaller in size than the original image. Afterward, dilation with a 3 x 3 pixels square structural element with a reference point at the center follows. The counting of black dots is started; if the amount of dots is smaller than a pre-defined threshold, it may be stated that it is a digital photograph because the image shows disjoint dots almost of the same size. This is due to the fact that in a digital image, ink is organized in a more or less constant area dot arrangement. On the other hand, if the resulting image shows dots with different sizes sometimes connected among them, we can be sure that it is an analogical print, because it takes place through chemical processes which prevent the formation of isolated dots.

An analog image appears in the Card as "printed" in a continuous way. In order to check that the dots are continuously arranged and disjoint, the former image is reversed and the connected components are labeled. If the number of colored label (objects) is few, this fact, together with the feature mentioned above, determines that the image is a digital one.

Once the kind of image has been determined, if the image happened to be digital, the next thing to do is to determine the spatial resolution with which it was printed. This should be 800 dots per inch, as per the aforementioned security measure. Calculating the spatial resolution is extremely important, because the Federal Electoral Institute imposed this value due to the fact that having commercial printers to print images with this spatial resolution would not be possible. The flowchart of the whole process to find out the spatial resolution of the printed digital image is shown below (Fig. 3).

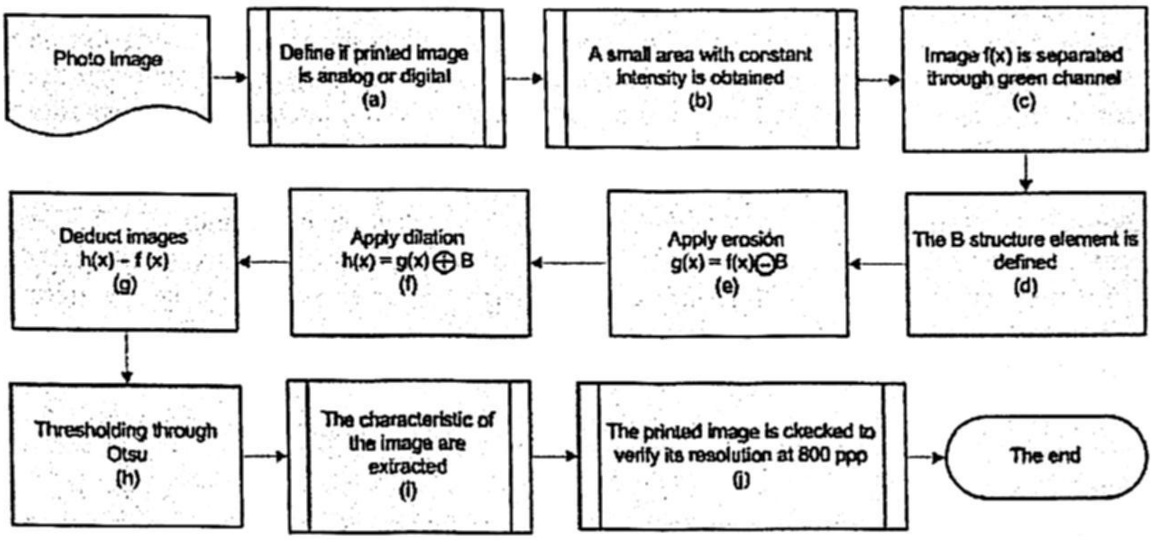

Fig. 3. Flowchart to find out the spatial resolution of the printed photograph.

An explanation of the whole process follows: Once the photograph is obtained, it is determined whether the printed image is analog or digital by using the methodology explained above, (a). If the image is found to be digital, a small square window is cut out from a pale area with more or less constant intensity, (b) with the size found through the Eq. (5).

$$Window\ size = \frac{1}{16} Scanned\ Resolution \quad (5)$$

where the window size is the area in pixels to be analyzed within the image.

The term 1/16 corresponds to the sixteenth part of an inch, which is the length of the side that corresponds to the square area to be analyzed; the scanned resolution is the value in pixels of the resolution with which the image to be analyzed was scanned. In our case, the images were scanned at 1200 dots per inch spatial resolution, it is important to know a priori the scanned resolution from the image in order to make the correct experimentation. If the scanned resolution is unknown it is necessary to calculate it by using specific algorithms or methodologies.

Therefore:

$$Window\,Size = \frac{1}{16}(1200) \tag{6}$$

So:

$$Window\,Size = 75\,Pixels$$

After cutting the entire image the green channel of the color image is selected (c). Once this is done, a cross-shaped structure element (d), whose size depends on the size of the printing dot, is defined. The higher the spatial resolution of the printed photograph the smaller each dot area of the printed image.

Then erosion is applied to the image (e) followed by dilation (f) with the same structure element (Opening). After this step, the original image is extracted from the resulting image (Top-hat), allowing us to see where there is more density of printed dots (g). In the next step the image is thresholded with the Otsu (h) method and the objects are labeled to be able to obtain the characteristics of the resulting image (i); the number of (colored) objects included in the labeled image is counted through Equation (7). These colors are found experimentally with this empiric equation, with which we can get the total number of objects avoiding the colors having similar values when they are counted. The formula calculates different values without repetition, because the range of values is wider than the calculated RGB average.

$$Color = 64(R+25) + 16(G+25) + 2(B+25) \tag{7}$$

Finally, empirical Equation (8) is used to find out if the resolution corresponds to the 800 dots per inch expected in the selected image fragment, in order to be able to assert that the whole photograph is genuine (j).

$$Resolution = \sqrt[2]{Points} * \frac{16}{1} * 2 * \frac{Scanned\,Resolution}{Printed\,Resolution} \tag{8}$$

Where the *Number of Dots* is given by the number of dots counted in the image. The term 1/16 corresponds to one sixteenth of an inch, which is the size of the sides of the square area being analyzed; 2 corresponds to the two dots, a white dot and a black one, which unavoidably make-up the spatial resolution unit. The Scan Resolution refers to the resolution with which the image was scanned and the Print Resolution is the resolution with which the original digital image is supposed to have been printed.

In this case, the image was scanned with a 1200ppp resolution and the printed image must be at 800 dpi in line according to the security measure with which the photograph must have been printed to be considered as genuine. Therefore, the formula would be now as follows:

$$Resolution = \sqrt[2]{Points} * \frac{16}{1} * 2 * \frac{3}{2} \tag{9}$$

This becomes:

$$Resolution = \sqrt[2]{Points} * 48 \tag{10}$$

Once the number of dots in the labeled binary image (previously thresholded by the Otsu algorithm) has been calculated, the final spatial resolution that checks if the photo in the Card was printed at 800 dots per inch is obtained through Eq. (10).

5 Experiments and Results

In order to confirm the proposed method, several experiments with different Card models were carried out. For this purpose, 30 Card images were used: 10 with analog photographs and 20 with digital photographs printed with an 800 dpi resolution. All of them were scanned at 1200 pixels per inch (ppi) by using an HP Scanjet 367Q scanner.

When we applied the first method to find out the kind of image printed on the Card, the results shown in Table 1 were obtained. The results indicate that the method produces a correct classification always in both kinds of prints.

Table 1. Classification results with the first methodology.

Printing type		
Samples	Analog	Digital
30	10	20

When we applied the second method, once we found that the photo printed on the Card was digital, we had to find out if the space resolution of the print was 800 dpi. The results shown in Table 2, show that there is a false negative, because the expected resolution was not obtained due to the fact that when we made the cut, the image with a dark shade was used.

Table 2. Classification results with the second methodology.

	Resolution (dpi)	Number of objects
	800	19
	700	1
Total objects		20

In order to determine the efficiency and yield of both methodologies, measurements were taken with the Precision and Recall methods, having obtained the results included in Table 3, where we may see that in the first method a 100% efficiency is achieved for a correct classification of each of the analyzed objects. In the second method a 96.6% efficiency is achieved.

Table 3. Efficiency of both developed methodologies.

	Samples (Total)	Correct Classification	Wrong Classification	Coverage	Recall	Precision
Methodology 1	30	30	0	100%	100%	100%
Methodology 2	30	29	1	100%	96.6%	96.6%

6 Conclusion

The methodologies proposed herein allow the reliable and robust determination of the kind of print of the photos included in the Mexican ID-Cards, and in case the print is digital they allow verification of the fact that the spatial resolution corresponds to the one established by the Federal Electoral Institute: 800 dpi. These methodologies based on the top-hat morphological transformation, allows us to emphasize the interesting areas of the image (printed points). The size of the window selected for analysis is empirically defined through a formula. The size of the structure element plays a role in both methodologies, because the higher the expected space resolution, the smaller the structure element required. On the other hand the lower the resolution the larger the size of the structure element. With the first method the efficiency was of 100% and with the second method an efficiency of 96.6% was achieved. These results can be used, together the alphanumeric data printed in the document and related to its proprietary, to decide if an ID-Card is genuine or apocrypha.

Acknowledgements. The authors would like to thank COFAA, Postgraduate and Research Secretary, and Center for Computing Research of the National Polytechnic Institute, CONACyT and SNI, for their economic support to carry out this work.

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