A Methodology to Determine the Resolution of the Photograph Printed in the Mexican ID-card

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Abstract. The following paper shows a methodology to determine if the picture appearing on the ID-card is a digital 800 dots per inch (dpi) image. This "non-official" document is used as the main identification card in Mexico. For this methodology the basic concepts of mathematical morphology, such as dilation and erosion and the top-hat transformation are used to extract characteristics by using a previously defined structure element on the digital photograph. Subsequently the threshold is applied and the image is labeled to count the number of black dots contained in the resulting image. This procedure tells us if the picture printed on the ID-card is authentic. The analysis is carried out on the photograph scanned at 1200 dpi.

1 Introduction

The ID-card with photograph is a document issued by the Instituto Federal Electoral (IFE) (Federal Electoral Institute), which is autonomous. The Id-card is used to vote in local and federal elections in Mexico. Despite the fact that this Id-card is NOT an official document, it has become the main identification for Mexicans. It is the only Id-card issued to 18 year old and older citizens and it is also used for bank and cash transactions, and even to allow entry to night clubs or to sell cigarettes or alcoholic beverages to bearers in Mexico.

The ID-card has many shields and safety measures against forgery [1] [2]. One of the security measures mentioned in this paper relates to the photograph printed on the ID-card, which has some characteristics to discourage forgery.

Two kinds of photos are printed on the ID-card: the analogical photo, obtained with a conventional Polaroid [3] camera and a digital photo in the back, with an 800 dots per inch (dpi) resolution. This difference is due to the fact that before 2001 the IFE did not have the technology to print photos on plastic cards, so they used snapshots from a commercial Polaroid (analogical image) camera (Fig. 1a). Subsequently, the IFE decided to print the photo digitally, with 800 dpi resolution (Fig. 1b) [4].

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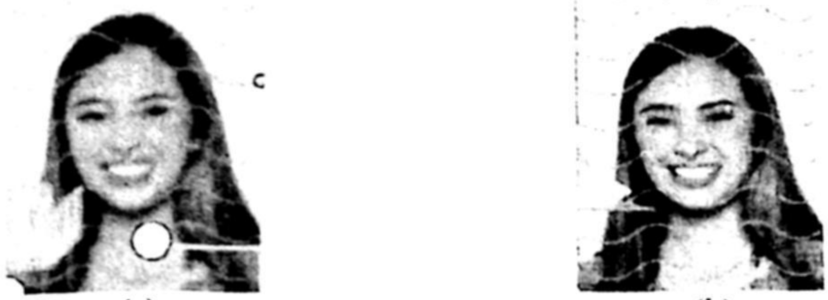


(a) (b)

Fig. 1. Id-card Photos: a) Analogical, b) Digital with 800 dpi resolution.

2 Main Objective

The ID-card contains several security measures that make the document secure and impossible to duplicate. Nowadays there are no systems in Mexico capable of identifying a forged ID-card. Therefore, we are looking for a methodology that will allow us to authenticate ID-card photos which should be printed with an 800 dpi resolution as their special characteristic. With this information and other features, we will be able to decide on the authenticity of the Id-card.

3 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* being among the most common measures. Suppose that we draw a chart with alternating black and white lines, each of width W units (*W can be less than 1*). The width of a *line pair* is thus $2W$, and there are $1/2W$ line pairs per unit distance. For example, if the width of a line is 0.1mm, there are 5 line pairs per unit distance (mm). A widely used definition of image resolution is the largest number of *discernible* line pairs per unit distance (e. g., 100 line pairs per mm). Dots per unit distance are a measure of image resolution used commonly in the printing and publishing industries. In the U. S., this measure is usually expressed as *dots per inch* (dpi). As an idea of the difference in quality, newspapers are printed with a 75dpi resolution, magazines with 133dpi, glossy brochures with 175dpi, and some books with 2400dpi [7].

4 Morphological Image Processing

Mathematic morphology is based on shape and geometry. Morphological operations simplify the image and preserve the main forms of objects. Mathematical morphology uses point set theory as well as the results of integral geometry and topology [9].

4.1 Top-Hat Transformation

One of the main applications of these transformations is removing objects from an image by using a structuring element in the opening or closing operations over objects that do not fit in it. The top-hat transform is used for clear objects located on a dark background; for this reason, the name *top-hat* is used frequently when we refer to this transformation. A common use of top-hat transformations is correcting the effects of non-homogeneous illumination [7].

The *top-hat transformation* of a gray-scale image *f* is defined as the original image,*f*, *minus its opening* (Eq. 1):

$$Thatf=f-(f \circ b) \tag{1}$$

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

The *opening* of a set *A* by a structuring element *B*, *denoted A or B*, is defined as (Eq. 2):

$$f \circ b=(f \ominus b)\oplus b \tag{2}$$

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 *Opening* generally smoothes the contour of an object, breaks narrow isthmuses and eliminates thin protrusions [12].
The *Erosion* is defined as (Eq. 3):

$$f \ominus b(x,y)= mins,t\in b\{f(x+s,y+t)\} \tag{3}$$

The *Dilation* is defined as (Eq. 4):

$$f \oplus b(x,y)= maxs,t\in b\{f(x-s,y-t)\} \tag{4}$$

5 Methodology

Fig. 2 shows the flowchart of the methodology used to verify the spatial resolution of the photos printed on ID-cards. First we digitalize the ID-card with a resolution over the printed ID-card photo (in this case 1200 dpi) obtaining the area of interest, which is the photo (a). When we have the photo we must determine if it was analogically or digitally printed, by using the methodology employed in [13] (b). Later, if the photo happens to be digital, we cut a small portion of the image; the size of the area is determined by equation 5.

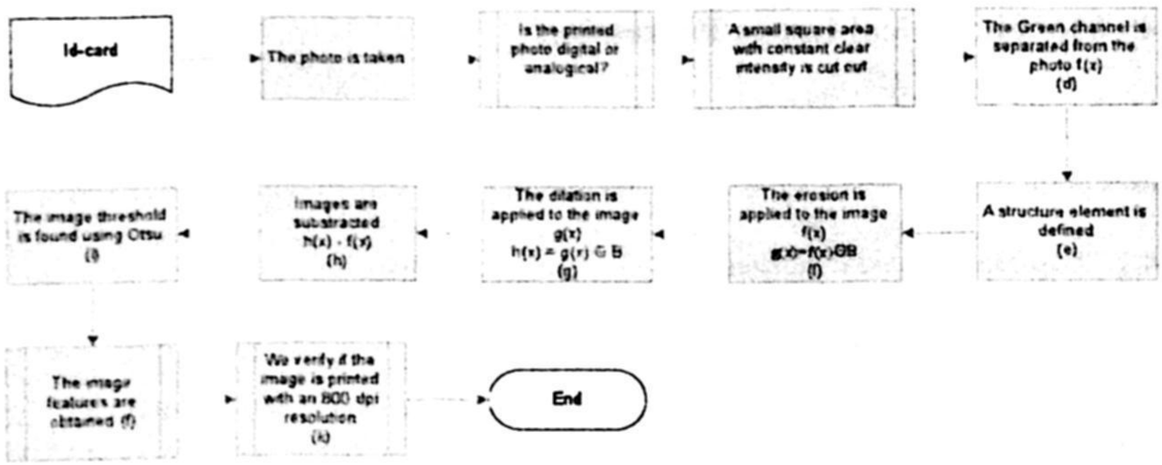


Fig. 2. Block diagram of the methodology used.

$$\textit{Window size= 116Scanned Resolution} \quad (5)$$

Where the *Window size*, is the size in pixels of the area to be analyzed in the photo. ***116*** corresponds to a sixteenth part of one inch, that is the area that must be verified; the Scanned *Resolution* is the value in pixels of the spatial resolution with which the image was digitalized.

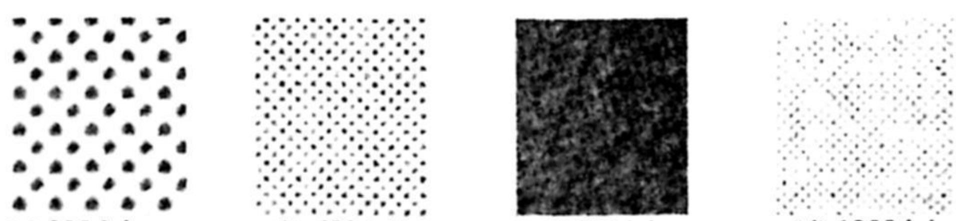
In this case images where scanned in a 1200 dots per inch spatial resolution, so:

$$\textit{Window Size= 116(1200)}$$

Therefore:

$$\textit{Window Size=75 Pixels}$$

Subsequently to the cut (c) the Green channel of the image is selected (d). Then a square *structural* element must be defined (e) which size depends on the size of the printed dot. The greater the spatial resolution of the printed photo, the smaller the area of each one of the printed dots in the image, as we can see in Fig. 3.



(a) 300dpi (b) 600dpi (c) 800dpi (d) 1200dpi

Fig. 3. Square image with dots in a different spatial resolution.

Then, the erosion is applied to the image, followed by the dilation with the same structure element (opening). Then the original image is subtracted with the result image (top-hat), so we can see the points where the ink has been printed in more quantity. Next, we threshold the image using Otsu [6] and we label the objects to finally get the features of the image; in this case, we label the points using different colors [8], then we count the total colors that appeared in the labeling image using equation 6, obtained experimentally; this equation allows us not to repeat the same color twice.

$$Color=64R+25+16G+25+2(B+25) \quad (6)$$

Where R is the color value in the Red channel, G is the color value in the Green channel and B is the color value in the Blue channel.

Finally, equation 7, which was determined empirically, is used to find out if the resolution corresponds to the 800 dots per inch in the area of the image and then the photo may be considered to be genuine.

$$Resolution= 2Points*161*2*Scanned\ ResolutionPrinted\ Resolution \quad (7)$$

Where:

Points is the number of the points that appeared inside the area which are approximately the same area; number *16* corresponds to the sixteenth part of an inch, that is the area that we analyzed; number 2 corresponds to the two points, one black and one white, that implicitly integrate spatial resolution; *Scanned Resolution* refers to the resolution of the digitized image; *Printed Resolution* means the assumed resolution of the original digital image.

In this case, the image was digitalized with a 1200 dpi spatial resolution and the printed image must be in the 800 dots per inch range according to the secure measure with which the photo was printed. Therefore, the formula is:

$$Resolution= 2Points*161*2*32 \quad (8)$$

So, the formula is reduced to:

$$Resolution= 2Points*48 \quad (9)$$

When the number of dots printed in the image through the Otsu algorithm is known, the resolution is obtained with formula 9 and we verify that it corresponds to the 800 dots per inch of the printed digital image.

6 Experimentation and Results

To corroborate the methodology, we made some experiments using genuine ID-cards digitalized with 1200 dots per inch (dpi) using an HP scanner, 367Q HP Scanjet along with some other printed images with different spatial resolutions: 300, 600, 800 and 1200 dpi.

Fig. 4. Digital photo from an ID-card.

From each image selected for the experiment we applied the previously described methodology (obtained from a clear area of the photo) and we applied the morphological transformations to get the printed dots and determine the spatial resolution of the print.

Fig. 5. Image of the square area to be analized.

In the methodology we used a 7 x 7 pixels square structure element in a disc form with reference point in [3,3] as we can see in Fig. 6.

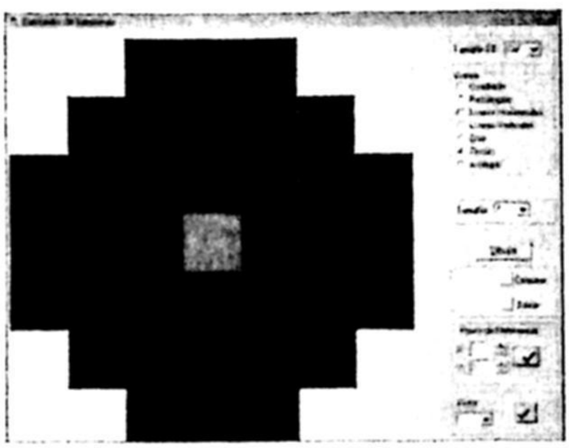


Fig. 6 Disc-shaped structuring element (SE).

We separated the image in the Green channel, then we eroded the image with the established SE, and we observe the resulting black points (Fig. 7), where the area in which more ink was printed, appeared smaller due to erosion:

Fig. 7. Green channel eroded

Then, we dilated the last image (Fig. 7) with the same structure element. In the resulting image it can be observed that the black points dilated and manifested themselves in a more clear manner (fig 8). This image represents the opening of the image in Green channel.

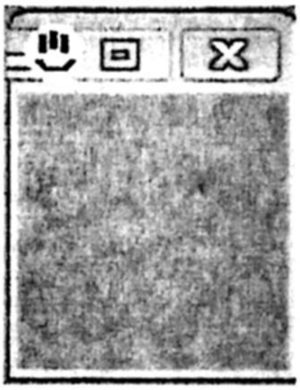


Fig. 8. Dilated image.

Subsequently, we applied the top-hat transformation using the subtraction of the original image and its opening, getting as result Fig. 9, where the points which were printed in the digital photo can be observed:

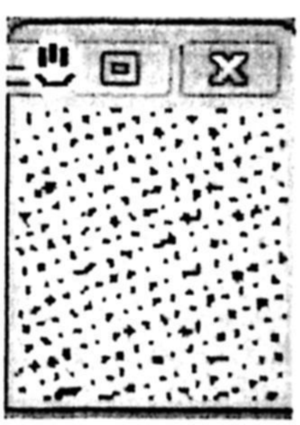


Fig. 9. Subtraction of the original image and his opening.

We threshold the image using Otsu's algorithm:

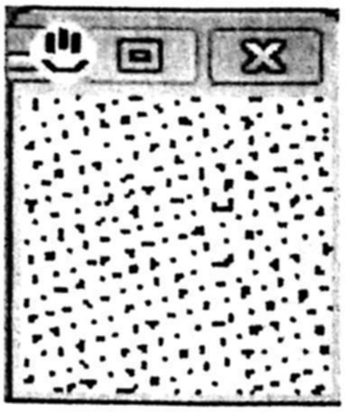


Fig. 10. Threshold image.

We labeled the points of the image and counted each color appearing in the image:

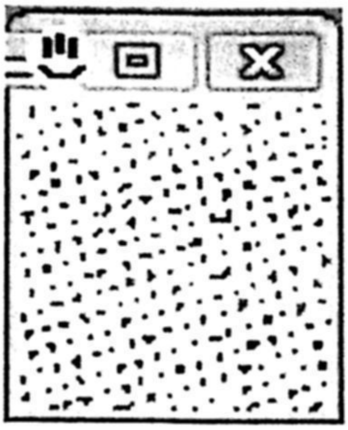


Fig. 11. Labeling image.

For this case, the result of the counter was:

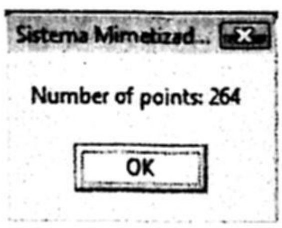


Fig. 12. Counter.

Then, we applied equation (9) and we got the following result: **779.91** dots per inch. The difference with 800 dots per inch is because when we used the morphological operation on the image, the image loses some details. Some points that are in the original image, because of their size, tend to disappear during the initial opening.

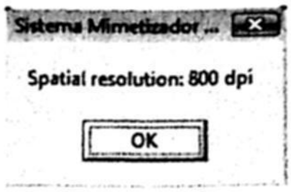


Fig. 13. Final counter.

This same procedure was applied to 16 different id-cards, and we got the following results (table 1):

Table 1. Experimentation results

Sample	Points	Resolution (Formula) (dpi)	Resolution (Round) (dpi)
1	211	697.24	700
2	246	752.85	800
3	246	752.85	800
4	247	754.38	800
5	256	768.00	800
6	256	768.00	800
7	259	772.49	800
8	259	772.49	800
9	260	773.98	800
10	264	779.91	800
11	267	784.33	800
12	269	787.26	800
13	269	787.26	800
14	271	790.18	800
15	272	791.64	800
16	278	800.32	800

In sample #1, the result is 697.24 dpi due to the dark intensity tones in the sampled image, as we can see in Fig. 14. It must be remembered that the previously described methodology does not work for dark intensities for they don't permit correctly getting the number of printed points (recall the top-hat definition). It is necessary to use clear zones that allow the correct transformation.

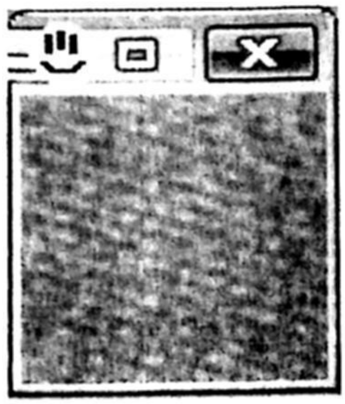


Fig. 14. Image from an area with dark tones.

In the rest of samples we did not get exactly 800 dots per inch (only in the sample 16) because generally the image loses some points when the morphological operations are applied. Afterwards, we made some experiments on analogical images, with the aim to check that the proposed methodology works correctly when the images are not digital images.

The original image of the green channel with 75 x 75 pixels (Fig. 15a) we apply the erosion (Fig. 15b) with the same disc shaped structuring element of 7 pixels diameter and then we apply the dilation (Fig. 15c); after that we subtract the resulting image (opening) from the original image (Fig. 15d) and we threshold it by using Otsu (Fig. 15e); then we label the image (Fig. 15f) and count the number of points with different colors in the image.

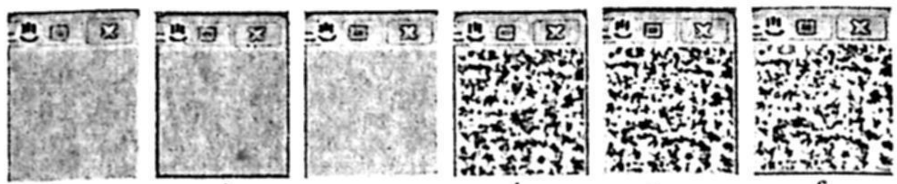


Fig. 15. Analysis of an analogical image.

The result was: *Number of points*: 182; *Resolution*: Analogical Image.

The same procedure was applied in a similar way to the following printed samples with a spatial resolution of 300, 600 and 1200 dpi. The results were:

a) For a digital image printed at 300dpi (Fig. 16):

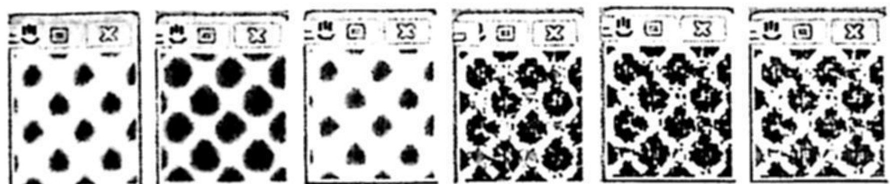


Fig. 16. Analysis of the digital image printed at 300 dpi.

Number of points: 49; *Resolution*: 336dpi; *Rounded* 300dpi.

b) For a digital image printed at 600dpi (Fig. 17):

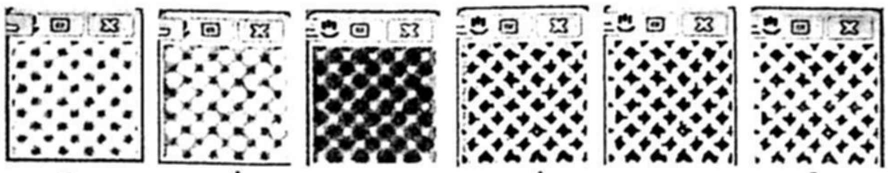


Fig. 17. Analysis of the digital image printed at 600 dpi.

Number of points: 65; *Resolution*: 386.99dpi; *Rounded*: 400dpi.

c) For a printed digital image in 1200dpi (Fig. 18):

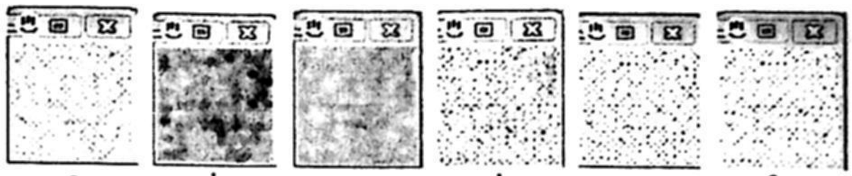


Fig. 18. Analysis of the digital image printed at 1200 dpi.

Number of points: 396; *Resolution*: 955.16dpi; *Rounded*: 1000dpi

As we can note, the results do not approach to the expected spatial resolution because images were printed at a different resolution that we wanted to determinate. Nevertheless, the results obtained in these cases allow us to asses that the images were not printed at 800dpi.

7 Conclusions

We can asses that the methodology proposed in this paper is a reliable way to determine the spatial resolution of the photo printed at 800dpi in the ID-card. This methodology is based on basic morphological operations such as dilation, erosion and the *top-hat* transformation. The *top-hat* transformation must be applied on clear areas of the image, in order to avoid errors on the resolution calculation. Subsequently, we threshold the image using the Otsu method and we label the resulting image in order to count the number of points with different colors in the image. The area size of the analysis is defined by the scanned resolution multiplied by the sixteenth part. The size and shape of the structuring element plays an important role in the methodology; the greater the spatial resolution, smaller must be the size of the structuring element; in the other hand, the smaller is the spatial resolution the greater must be the size of the structuring element. Once we have counted the points in the thresholded image. The methodology does not allow getting exactly the final resolution because when the morphological operation is applied on the image, some details is lost, that is some points present in the original image, because of their size, tend to disappear after the initial opening. When the final result is closest to 800dpi, we can asses that the photo was printed at that resolution.

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