Virtual Lab for histogram-based binarization of gray level images: Heuristic threshold

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The creation of a Virtual Lab, integrated and interactive software, to perform histogram-based binarization of gray scaled images is reported. In an attempt to optimize the binarization the developed virtual lab introduces a Heuristic Binarization Threshold. At processing time, the module extracts the histogram of the input gray scaled image, and then a Heuristic Threshold is calculated by taking the weighted average of the foreground grey levels of the image. Next those pixels in input image whose grey levels are above this threshold are highlighted. Although still not experimentally optimum, this heuristic threshold provides a first approximation towards automatic optimum binarization of grey scaled images. For comparison purposes when an input image is operated on by the binarization module, it is possible to visualize up to three different binarizations on screen simultaneously, each for a different binarization threshold fixed by the user.

Keywords: Virtual Lab, digital image processing, automatic binarization, gray scale histogram, heuristic threshold.

Virtual Lab para la binarización vía histograma de imágenes en niveles de gris: Umbral heurístico

Se reporta la creación de un Virtual Lab, software interactivo e integrado, para llevar a cabo la binarización basada en histograma de imágenes en niveles de gris. En un intento de optimizar la binarización, el Virtual Lab que se reporta introduce un umbral heurístico de binarización. Durante el procesamiento, se extrae el histograma de la imagen y el módulo calcula un umbral heurístico, para lo cual extrae el promedio ponderado de los niveles de gris del primer plano de la imagen. A continuación se resaltan los niveles de gris en la imagen que están por encima del umbral detectado. Aunque aún no es experimentalmente óptimo, el umbral heurístico proporciona una primera aproximación hacia la óptima binarización automática de las imágenes en niveles de gris. Cuando el módulo opera sobre una imagen, es posible visualizar y comparar en la pantalla hasta tres diferentes binarizaciones simultáneamente, cada una para un umbral diferente de binarización fijado por el usuario.

Palabras claves: Laboratorio virtual, procesamiento digital de imágenes, binarización automática, histograma de niveles de gris, umbral heurístico.

When the information of an image is contained in the shape of the objects within the image rather than in their color, it is convenient to convert the image to strict black and white, this is, to *Binarize* the image. The need of binarized images arises not only in automatic digital image processing applications like industrial quality control, but also when a professional, may be a physician, makes a diagnostic based on plain image visualization. For instance, in echography of the prostate, the silhouette of this shows up rather blurred. In a case like this it would be better to have an image displaying a very well defined shape of the prostate. A first step towards a neat image is binarization of the image resulting from the echography.

Binarization of images is the indispensable pre-processing in some pattern recognition applications of digital image processing [1–6]. Binarized images are used in those applications focusing on the shape of the objects in the image under scrutiny, like industrial quality control, security and defense systems, medical diagnostics, etc. For an example, see Fig. 1.

Binary images are used in quality control in modern industrial plants, for automatic shape imperfection detec-

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tion. As an example consider the silhouette control of plastic-material pieces produced by an injector machine in a factory. Another example may be the case of factories of chocolates, wafers and biscuits, where pattern recognition techniques may be used to detect flaws in the shape of the sweet pieces. When these pieces must keep a rectangular or squared shape, a technique that may be implemented to achieve this shape control may be based on the Polar Hough Transform [1, 2], which performs on strictly black and white (binary) images. Other Hough-transform based algorithms may also be used to detect the perfection of circular and elliptical shapes.

For the sake of quickness, pattern recognition applications in defense systems must operate upon binary images. These applications might make use of algorithms based on Invariant Moments [1, 2], which require a pre-processing to binarize grayscale images before extracting information from them.

Sources of digital images are the visible radiation, thermography, nuclear magnetic resonance (NMR), ultrasound for sonography and echography, computer tomography, etc.

Histograms

The histogram [1, 4] of a grayscale digital image gives the number of pixels per gray level in the image. In this way the histogram gives also information about the probability of finding a given gray-level in the image, the higher the number of pixels for a given gray level, the higher the probability of finding that gray level in the image, and vice versa.

In order to obtain the grey-level histogram [7, 8] of an image, a census to make a list of number of pixels per grey level must be made, see Table 1. The histogram is the plotting of number of pixels versus grey level. In this way the horizontal axis of the histogram ranges from 0 (dark levels) through 255 (clear color levels), and the vertical is the pixel population in each grey level. One way of executing this census is, sweeping top-down and left-right the image and counting the number of pixels having every one of the 256 gray levels from 0 through 255.

Histogram equalization

A histogram has been equalized [1, 4] when it has been normalized between 0 and 1, with 0 representing black and 1 signifying white. In this way the gray levels may be regarded as random quantities in the interval from 0 to 1.

In the Virtual Lab being reported here, the histogram is rendered on screen and as the mouse hovers over it, the grey-level under the mouse and its population is reported. In order to fix the binarization threshold, one of these grey-levels on the histogram must be mouse clicked, or selected by displacing a scroll bar.

Number of pixels by gray level	
Gray level	Pixels
0	91458
1	2995
2	1264
3	996
4	723
5	566
6	443
7	341
. . .	. . .
. . .	. . .
. . .	. . .
250	558
251	827
252	1199
253	1871
254	3129
255	37786

Table 1: An example of a table of pixel population per gray level: The grey levels run from 0 through 255 and, every grey level is associated to the numbers of pixels in input image having that level. The histogram is made by plotting population versus grey level. In a normalized histogram the grey level runs from 0 through 1.

Setting a binarization threshold

As binarization threshold any of the 256 gray levels may be selected, this is, the binarization threshold is a number between 0 and 255. During binarization pixels whose gray levels are below the selected threshold are ignored and those above it are highlighted.

Setting a binarization threshold is not an easy task because it depends on the image and on the requirements of the work being carried out. A computerized pattern recognition system may require very well defined edges of solid objects, while a physician might need a visualization of the soft tissues in the human body.

Thresholded binarization

In order to achieve the grayscale image binarization, the image may be scanned top-down and left-right, and those pixels in the image whose grey-levels are above the predefined threshold must be highlighted [7, 8], by for example, showing them in white colour on a black background, or vice versa.

Heuristic thresholding

Usually grayscaled images have dark colours, especially black, as the background and clear colours, especially white, as foreground. Experimentally, when the weighted

average grey level was used as a binarization threshold the resulting binary image was not as good as expected. The same happened when taking as a threshold the most populated grey level.

In the binarization module being described here a heuristic binarization threshold is obtained by automatically discarding the background dark grey levels from 0 through 40, and taking the weighted average of the remaining levels as the binarization threshold. In this way, the module introduces as a suggested threshold, the weighted average of the assumed foreground grey levels, those from 41 through 255. Many images were tested with this heuristically obtained threshold and the results were not always as good as expected. The method used here to obtain a heuristic threshold might be considered a first approximation towards the automatic detection of an optimal binarization threshold.

Alternating background-foreground colors

Usually in gray leveled images the background colors are dark, starting at black, and the foreground colors are rather clear with white as the maximum. Sometimes it is necessary to know the appearance of the binarized image if the background and foreground colors were switched. The module being reported here makes this possible. An option is included so that background and foreground colors are interchanged during binarization.

Results

The Virtual Lab (interactive and integrated software) being reported here operates on gray leveled input images. Once an image is loaded, a click of a button extracts the normalized histogram of the image and calculates (and reports) the heuristic threshold. Automatically the binarization threshold selector is set on the value of the heuristic threshold, so that the user only has to click another button to generate a binary image binarized with the heuristic threshold. For an input image the user may set as many binarization thresholds as desired, generating in each case the corresponding image. In order to allow comparisons, the reported module can display up to three binarized images at a time on screen.
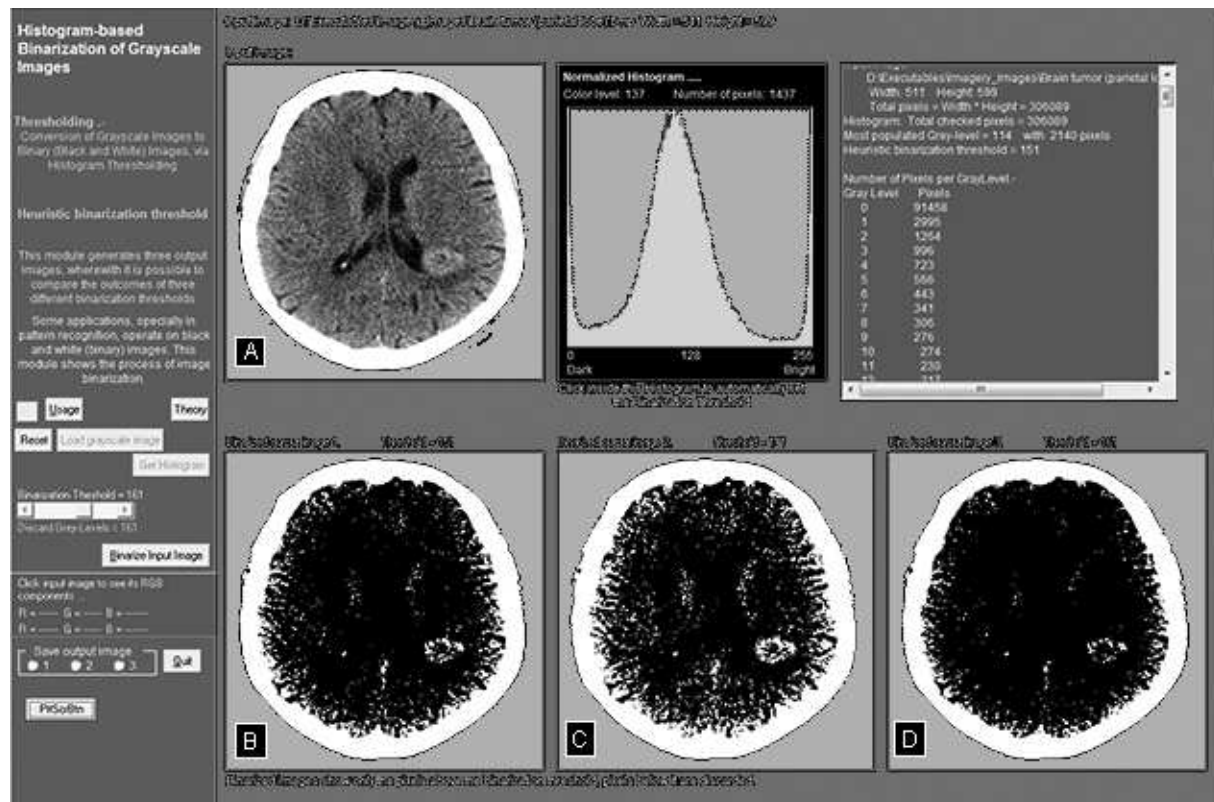

Figure 1: A view of the user interface of the Virtual Lab. At the top: the gray-scaled input image (A) showing from left to right a brain tumor in the parietal lobe, the generated Histogram and data. Below: (B) Binarized image obtained with the automatically calculated heuristic threshold, T=151. Images (C) and (D) are binarizations made for comparison purposes and corresponding to

T=141 and T=161, respectively.

The Figure 1, displays a panoramic view of the developed module. The gray scaled input image (A) at the top is a view of a tumor in the parietal lobe of the brain. Next appears the normalized histogram of the input image, where the user may click with the mouse in order to manually set a desired level of binarization. Next, at the top right appears some numerical data associated to the binarized image, which was generated during binarization. At the bottom of Figure 1, three binarizations (B, C and D) of the input image are shown. The best binarized image displaying the profile of the tumor is B and it was obtained with the automatically calculated heuristic threshold of T=151. With the aim on allowing comparison, two additional thresholds were tested, one above and another below the heuristic threshold. In this way, image C displays binarization with threshold T = 141, and image D shows a binarization with T = 161. It can be seen that result C highlights too many pixels in the image, generating confusion with tissue pixels around the tumor, while result D focuses very few pixels.

It is worth mentioning that not always the heuristically calculated binarization threshold generates the best binarization of input image.
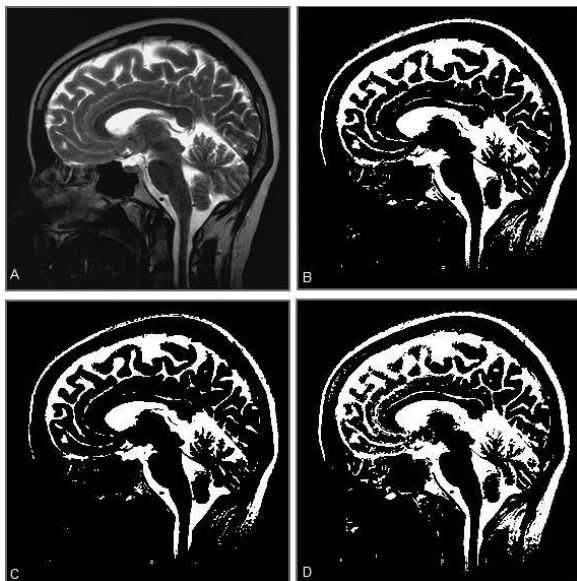
ages B, C and D are binarized output versions of A. The binarization based on the heuristic threshold (T=110) is displayed in B. The other two binarizations were obtained with user-defined thresholds of 120 in image C, and 100 in image D, respectively. It seems to be that the best binarization is obtained with a threshold of T=120, because the resulting image is neat and shows many details. It may be said that image C is better than image B. On the other hand, image D, with a threshold of T=100 is rather noisy and hence it is not so good. Fig 2 shows a situation where the heuristic binarization threshold calculated by the computer program produces an acceptable output, very close to the ideal, which seems to be image C, if not image B itself, because for some users image B would be better than image C.
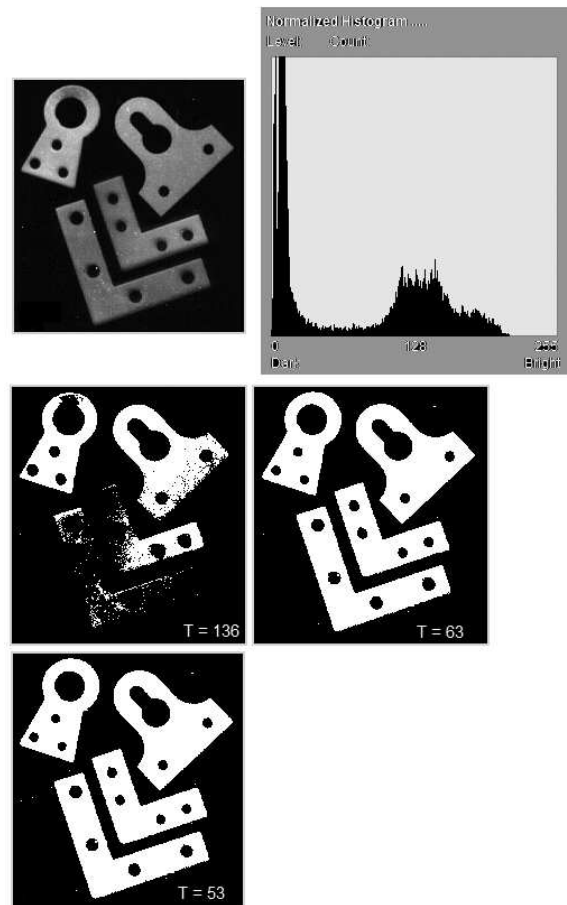

Figure 2: A magnetic resonance image (MRI) is shown in A as the input image. The others three images are linearized versions of A. The heuristic threshold determined by the computer program was T= 110 , and image B is the corresponding output. For comparison purposes images C with T=120 and D with T=100 were also generated.

In Figure 2, a gray-scale magnetic resonance image (A, input image) of the brain is submitted to binarization. Im-

Figure 3: (Top) Greyscale photograph of some metal accesories (input image) and its normalized histogram (Below): Three instances of binarization of input image with thresholds of 136, 63 and 53, respectively. In this case, the automati-

cally obtained threshold (T=136) generates a very low quality binarization.

The Figure 3 displays the binarization of an image displaying some metal accessories used in woodworking. In this case, the input image at the top left is a grey-level photograph of some metallic pieces. The corresponding normalized histogram is displayed at the top right. Then three instances of the binarization of the input image are shown below the input image. The corresponding thresholds are 136, 63 and 53, respectively. In this case the automatically obtained heuristic threshold is 136, the other two thresholds were selected by mouse clicking the histogram. As it can be seen in Table 1, different thresholds generate binary images of different qualities, and obviously in this case the best binary image has been manually obtained with a threshold of 53. In this case the automatically obtained heuristic threshold generates a poor quality binarization.

The Figure 4, displays the effect of interchanging background and foreground colors during input image binarization. At the top the input image is again the MRI of the brain used in Fig. 2, a gray leveled image. The binarized versions at the heuristic threshold of T=110 and at thresholds of T=105 and T=115 are also shown. The option of interchanging background and foreground colors is included in the developed software because some details may be highlighted in this way, choosing either option is up to the user.

Conclusions

An Interactive and integrated software (a Virtual Lab) to achieve modulated binarization of grayscaled images, based on histogram thresholding, has been created. The user of the module sets the binarization threshold by mouse clicking the desired gray level in the input image histogram, which is rendered on screen. With a virtual lab like the one being reported, the user may test several binarization thresholds very easily and in a very short time. With the aim on automatic thresholding, a heuristic binarization threshold based on the weighted average of the foreground grey levels in the image has been introduced. This not always generated the ideal binarization of the input image. It seems to be that the selection of the correct binarization threshold is more an art than a science.
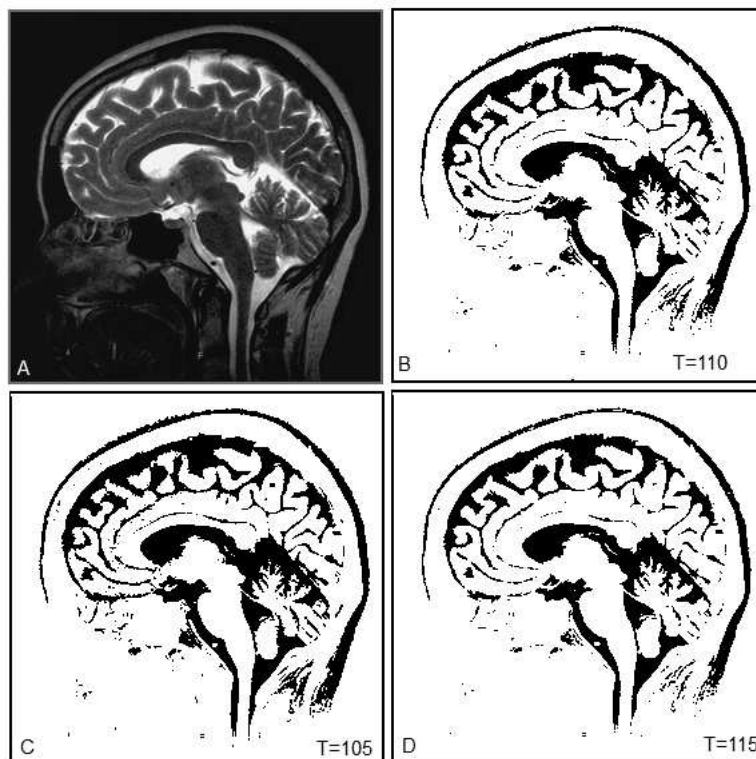

Figure 4: The developed software includes the option of interchanging background and foreground color during binarization. The input image is A, and B, C and D are the binarizations. The thresholds used in each case are shown.

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