A SOFTWARE TOOL TO COMPARE CONTRAST-DETAIL DETECTION IN UNIFORM AND IN REAL MAMMOGRAPHIC BACKGROUNDS

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ABSTRACT

A software tool is presented to merge CDMAM phantom images with real mammographic backgrounds. It allows SKE tasks in uniform and in real backgrounds. This kind of tasks can be used to compare human, human visual metric or model observer performance in detail detection using uniform or mammographic backgrounds.

As it is very well known, local characteristics of the structures in real mammographic backgrounds reduce the human performance in contrast-detail detection tasks. In consequence that performance cannot be inferred from the data acquired in white noise (flat) backgrounds such as a CDMAM phantom produces.

It is of interest to compare the response of a mammography system to the same set of signals, either embedded in flat or in real backgrounds. This comparison achieves two goals. The first one is to analyze the variation of the recognition threshold of the system for both backgrounds. The second one is to analyze the performance of a human observer or a model observer over the same set of signals, varying the nature of the backgrounds.

The software tool presented here uses CDMAM images to merge with a region of interest selected from a real mammography. This region as well as the mixing image method (basically adding or multiplying pixels) can be freely selected by the user. In this work a set of measurements of 8 images has been analyzed. We can preview the variation of the contrast-detail detection for a human observer and a human visual system metric (R*).

Keywords: Medical image perception, observer performance, mammography, CDMAM.

1. DESCRIPTION OF PURPOSE

The software tool presented here has been designed and developed to test the human observer performance in uniform and structured backgrounds, but also to compare the human observer behaviour vs. different Human Visual System metrics or model observers. By way of illustration of this ability, we have applied it to compare the performance of a Human Visual System metric, R* [1] and the human observer (HO) in real backgrounds. The main reason to choose this metric is that its behaviour in uniform backgrounds is very similar to that of the human observer.[2] Therefore, we have a reference to compare results when realistic backgrounds are considered.

2. MATERIAL AND METHODS

2.1. Background selection

The algorithm requires one CDMAM[3] image (Figure 1) and one background image, such as the one shown in Figure 2. The operator can choose by clicking the mouse, the upper corner of the ROI he wants to merge. First, the algorithm automatically locates the grid crossing points of a CDMAM image by applying a method previously designed.[2, 4, 5] It is demonstrated this method is simple, time effective and shows a very small error in the calculation of the crossing points (< 3 pixels) and the cell dimensions. According to these dimensions, the algorithm builds the rhombus that will be merged with each cell in the phantom and shows it to the operator (Figure 3). The operator can accept this ROI or can create a new one, clicking on the mammographic image on another position.
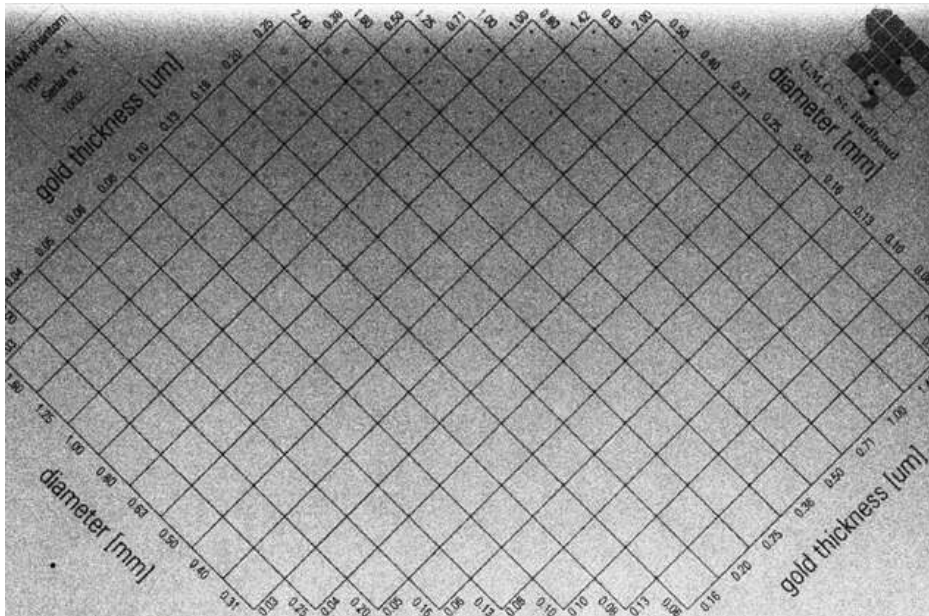

Figure 1. CDMAM image.

2.2 Merging methods

The system allows two methods to merge the phantom image with the mammographic background (Figure 4): linear additive or multiplicative. In case of linear additive, the algorithm computes the mean luminance value of the pixels of the selected rhombus in the mammographic background and takes this value as zero signal. This mean value is subtracted from the luminance value of each pixel of the selected rhombus. This gives a new rhombus with negative and positive values that is added, pixel by pixel, to each cell in the CDMAM image.

In the multiplicative method, the luminance value of the pixels in the mammographic background is divided by the average pixel value of the background (inside of the selected rhombus). These values are multiplied, pixel by pixel, to each cell in the CDMAM image. In addition, it can be introduced an attenuation factor for both methods increasing or decreasing the percentage of merging (Figure 4).

The selected ROI will be merged with each one of the CDMAM cells. Figure 5 and 6 show respectively the output of the algorithm and a detail of this new phantom image.
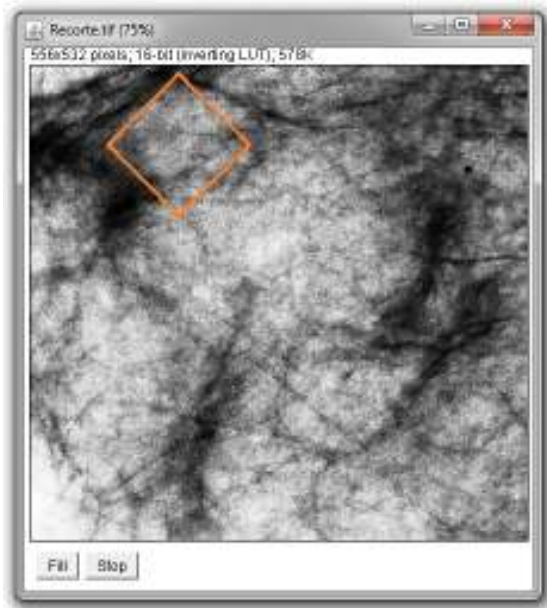
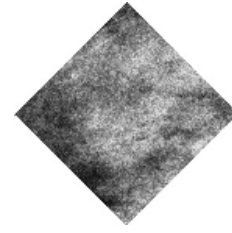Figure 2. Mammographic image

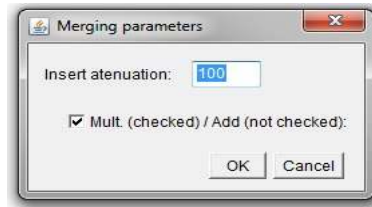Figure 3. Detail. Rhombus selection inside the background image

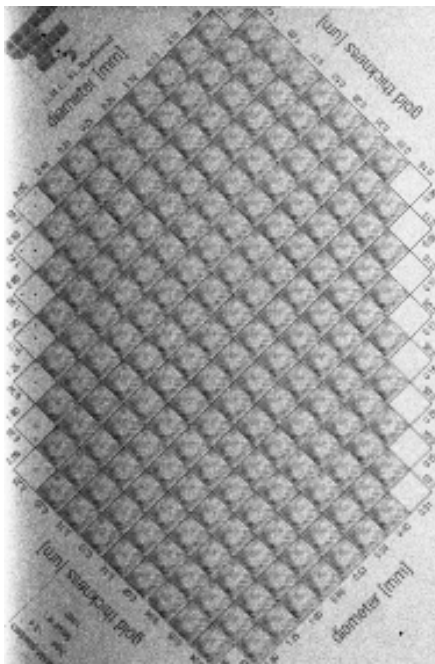Figure 4. Merging method and percentage of attenuation

Figure 5. Result of merging: CDMAM image superimposed with mammographic background
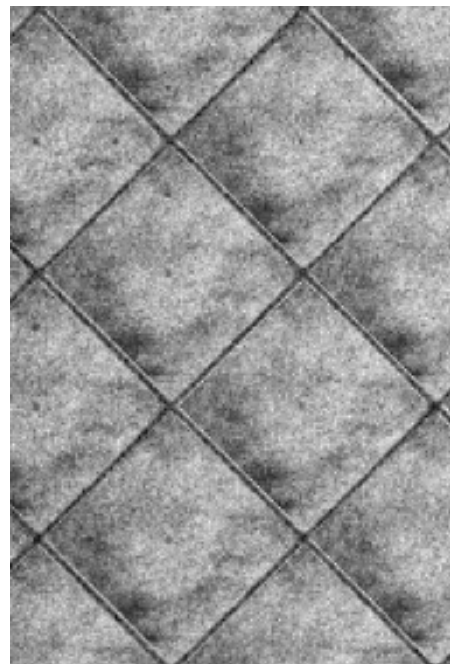

Figure 6. Result of merging, detail. Note the CDMAM discs inside the cells.

Every step in this method takes less than 0.5 seconds in a laptop with a processor Intel Core 2 Duo P8600, 4 GB RAM, Windows 7, Home Edition, 64-bits. We have developed our algorithms as a Java plugin to be used with ImageJ, the image manipulation program developed by Wayne Rasband. [6]

2.3. Set of images.

We have applied this software tool to one set of 8 CDMAM images, with the aim to obtain a preliminary result to test the efficiency of the method. These images were downloaded from the European Reference Organization for Quality Assured Breast Screening and Diagnostic Services (EUREF) web site.[7] The images were obtained with a GE Senographe 2000D at 27 kVp, 125 mAs and with a resolution of 1 pixel per 100 μm. These images were scored, according to the CDMAM rules of scoring,[3] by one observer with an experience of three years reading this kind of phantoms.

2.4. Performance comparison: relative efficiency.

To compare the performance of the HO and R*, we have applied the Constant Efficiency method. [8, 9] According to this method, the relative efficiency of R* versus the HO is defined as

$$Pc' = (Pc\ Human\ Observer/\ Pc\ R^*)^2 \qquad (1)$$

where Pc represents the figure of merit Proportion Correct.[10]

If the model is a good predictor, the relative efficiency Pc' should be approximately constant across the different conditions of the experiment;[10] in this work these conditions are the different diameters of the CDMAM discs.

RESULTS AND DISCUSSION

Figure 7 shows the contrast-detail curves obtained in four different conditions:

1) **R* Uniform** is obtained applying a metric (R*) to the mentioned set.
2) **HO uniform** is the corresponding contrast-detail curve for a human observer.
3) **R* Mammo** is the contrast-detail curve of R* obtained merging the previous CDMAM images with a mammographic background (this background is shown in figure 4)
4) **HO Mammo** is the corresponding contrast-detail curve for a HO. Note that the performance of both observers is almost the same for all disc sizes in uniform backgrounds, according to previous results.[2]

We have also computed the Relative efficiency (Pc') of the HO versus the metric R*. These results are shown in Figure 8. **Pc' Uniform** is the Relative efficiency of HO versus the metric R* in uniform backgrounds. **Pc' Mammo** is the corresponding ratio in mammographic backgrounds. Continuous lines are guides to the eye with no theoretical significance.

Attending to figure 7, three relevant facts can be observed in mammographic backgrounds. The first one, as expected, is the lower response of the human observer in mammographic backgrounds related to uniform ones, due to the structured noise in the image.

The second fact is the lower response of the R* metric in mammographic backgrounds related to the response of R* metric in the uniform backgrounds, as can be expected, due also to the higher (structured) noise presented in the image.

The third fact is that contrast threshold increases as disc size increases for disc diameters greater than 1.25 mm, due to the masking effects of the structures of the mammographic background. These structures have a size similar to the greater discs. This fact has also been reported by several researchers.[11, 12]
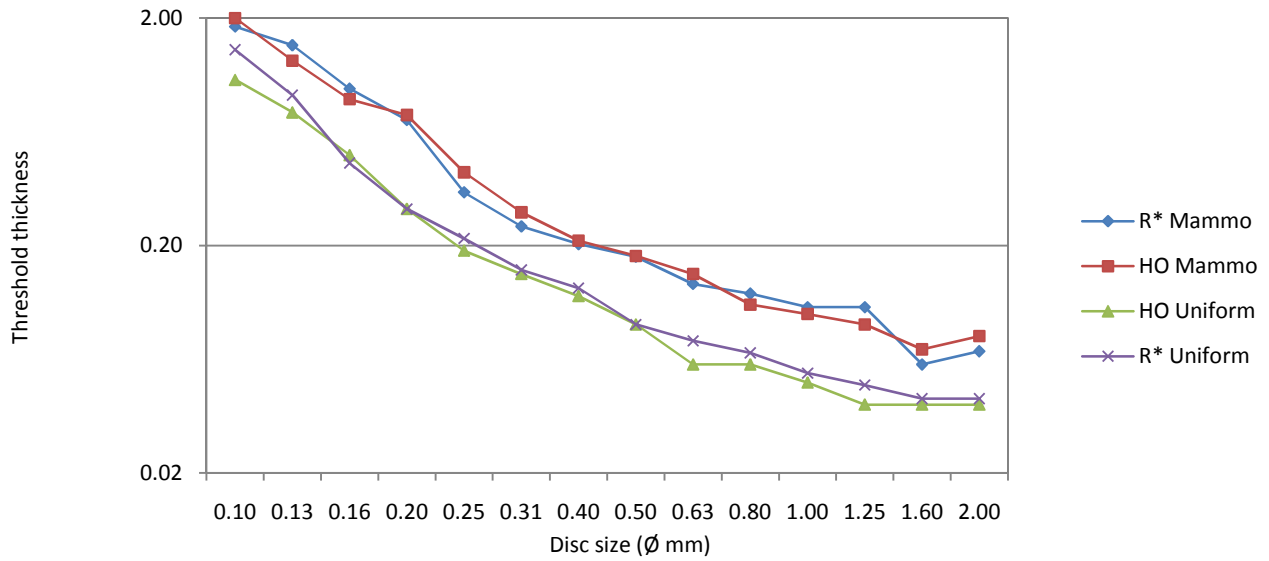
Figure 7. Performance variation in contrast-detail task for a human observer (HO) and a human visual system metric (R*) in uniform and mammographic (Mammo) backgrounds.
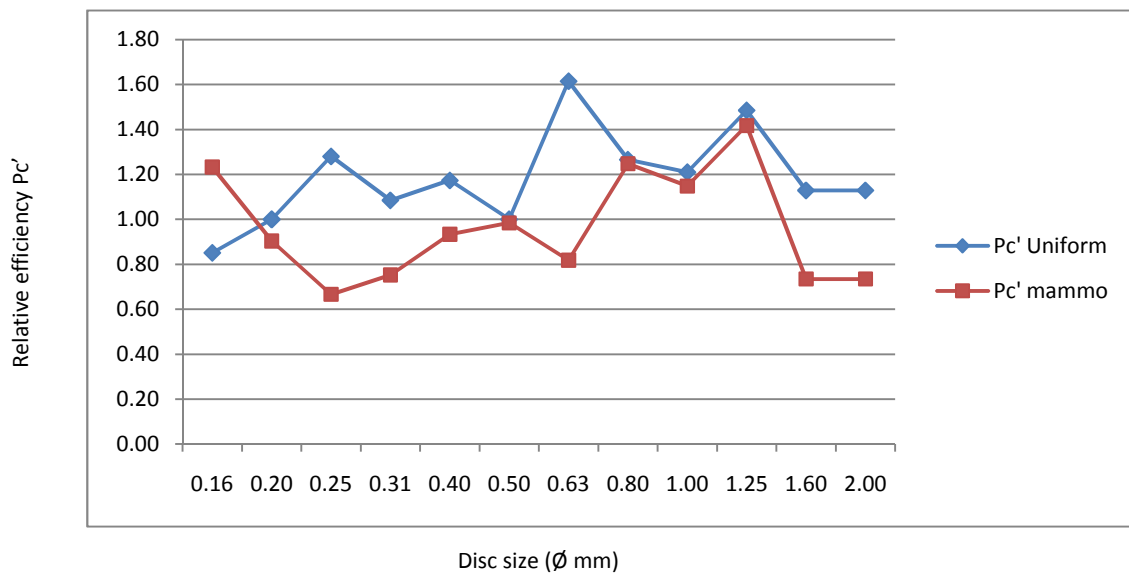

Figure 8. Relative efficiency Pc' in uniform and mammographic (Mammo) backgrounds.

Figure 8 shows that both observers have on average a similar sensitivity. Pc' has a mean value of 0.96 for mammographic backgrounds and 1.19 for uniform ones.

Figure 8 also shows that for diameters greater than 1.25 mm, the HO performance becomes much better than the R* metric performance. Other authors[11] have found a similar effect that is explained in terms of human readers performance. For details larger than 1mm, it seems that human readers could rely more on the disc edge than on the disc contrast. Moreover, a similar effect and explanation was also found by A. E. Burgess,[13] showing better human detection

using as inserts flat discs, with a high gradient of contrast at the edge, than using spheres, with a lower gradient of contrast at the edge than a flat disc. This fact implies the need to run this kind of test with real lesions (microcalcifications and benign or malign masses) better than with unrealistic sharp edge discs.

CONCLUSIONS

The new software tool presented in this work can be used to generate hybrid images merging CDMAM images and real mammographic backgrounds and to compare the performance of different observers (human or automated) for contrast-detail detection. Its application to an actual problem confirms the results obtained, similar to others well known by the scientific community, and shows its potential as tool of analysis of the performance of different observers.

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