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A CDMAM IMAGE PHANTOM SOFTWARE IMPROVEMENT FOR HUMAN OBSERVER ASSESSMENT

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Abstract. A software tool is presented to improve the features of CDMAM image phantom by University Hospital Nijmegen. This software tool ensures that the 4-alternative forced choice method of CDMAM is actually kept, even when is being scored by highly expertise observers familiar on the test object pattern. For digital images, the developed software tool automatically changes the image position of the four corners. It can be selected a fixed rotation angle or a random one, so making impossible that any observer is able to remember the exact corner position of the target disc inside any cell. Two alternative successful algorithms have been tested. ROC curve analysis obtained by 36 observers shows that both original and computer-modified images are indistinguishable. The ROC area was 0.507±0.024 for first algorithm and 0.522±0.026 for the second one, indicating that there was no statistical difference between real and computer-modified images for both of them.

1. INTRODUCTION

Many phantoms have been designed to study mammographic image quality such as ACR, TOR(MAM) or CDMAM phantom [i ii iii]. The task with these phantoms is to obtain the minimum contrast (threshold) for each diameter of a series of discs with different contrasts. Usually, the discs are located in well known positions and the evaluation is based in the SKE paradigm. The main advantage of the CDMAM phantom (Nijmejen) is that discs are located in one of the four corners of the 205 cells in which the phantom is divided. However, due to a group of discs is always seen while other group is never seen, the evaluation procedure is focused to a less number of cells. In addition, the tolerances established in some protocols for some discs could reduce the evaluation to a smaller number of discs. In consequence, the memory effect can not be rejected.

2. METHODS

We have developed our algorithms as a plugin inside ImageJ, the image manipulation program developed by Wayne Rasband [iv]. Our software developments will be periodically updated in the ImageJ website http://rsb.info.nih.gov/ij/plugins/index.html, including object and source codes, instructions of use and several test images.

The CDMAM phantom consists of an aluminium base with gold discs of varying thicknesses and diameters, which is attached to a Plexiglas cover. The discs are arranged in 16 rows and 16 columns. Within a row, the disc diameter is constant, with logarithmically increasing thickness. Each cell contains two gold disks each with the same diameter and thickness. One disk, the reference signal, is in the centre of the cell; the other, the test signal, is in one of the four corners.

Detection of grid position. In order to manage the disks information from the phantom images, it is necessary to accurately detect the position of the phantom grid where gold discs are inserted. Several methods have been applied to find this position [v, vi]. The method used in this work was designed to be simple and time effective on the basis that we have complete information about the geometry of the CDMAM.

We select a fixed ROI around the centre of the image with side dimensions of one third of the dimensions of the CDMAM. So, we can be sure that there are no unexposed bright areas or alphanumerical information that could affect our algorithms. Inside this area, we scan all pixels in the first and last columns. For each pixel we consider a fan of straight lines with origin at this pixel and ending on the other side of the ROI, within an angle range between 35 º and 55º, stepping one quarter of degree (Fig. 1). For each of these straight lines we calculate the addition of the pixel values. Maximum values of these additions indicate where the grid lines lie and which one is their angle. Maximum values from the ROI's first column allow us to detect negative slope grid lines and with the maximum values from the last column we detect positive slope grid lines. Both values give us the diagonal length (D) of the phantom cells, different for each side of the phantom. This fact probably can be due to the x-ray beam geometry. Using both data (angle and D), we extrapolate until the edge of the grid in the full CDMAM image.

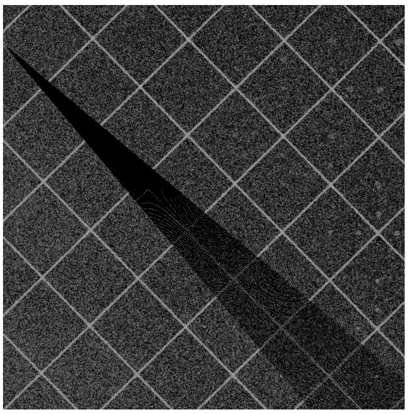

Fig. 1.

To assure the results, we scan around the intersection of each theoretical grid line with the edge. We repeat the process along the CDMAN grid edge in steps of D +/- 10 pixels around the expected points, looking for the better starting point of each straight line that better fits the grid. We run this process for both sides of the phantom. According the data of all straight lines, we calculate the intersection points of the grid. The distance between our calculated crossing points and the actual crossing points is between zero or one pixel. Only in a few cases for each image (<1%) this distance was equal or bigger than two pixels.

The main properties of this algorithm are:

a) Low computational consumption. The computing complexity for the central ROI calculations is of the order of 30 x n (where n is the number of pixels of the hole image). This complexity is of the order of n/10 for computing the algorithm for the rest of the image.[1]

[1] For instance, the time consumption for an image of 1628 x 2280 pixels, with 16 bits per pixel, using the first algorithm was 0.53 seconds and 0.56 seconds using the second algorithm, in a

b) No need of any kind of pre-processing, even for very noisy images

c) Robustness of the algorithm under very different conditions. The percentage of success detecting the grid was 100%. We have tested different images (40) from instruments from different manufacturers and models (LORAD-HOLOGIC, GE MEDICAL SYSTEMS, AGFA, FUJI) and with different levels of noise. The noise index (Std. deviation / mean value of the pixel) measured at a corner without grid lines, alphanumeric symbols or graphics, had values between 0,010 and 0,025. The angle of the detected grid lines had values between 43º and 47º. The only error we found a few times was a maximum shift of +/- 2 pixels between the calculated crossing points of the grid and the actual ones.

Phantom image manipulation. To avoid the memory effect of the expert observer, we have moved the corner disks in some cells. We have used two different algorithms, very well illustrated in Fig. 2 and 3.

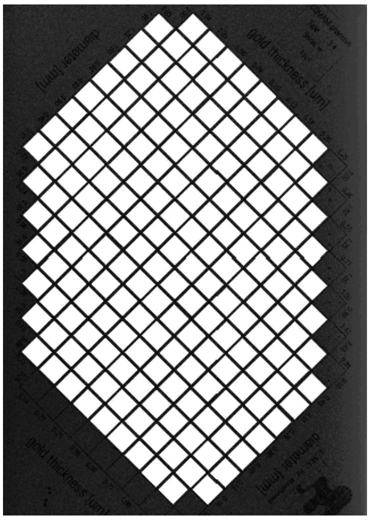

Fig. 2.

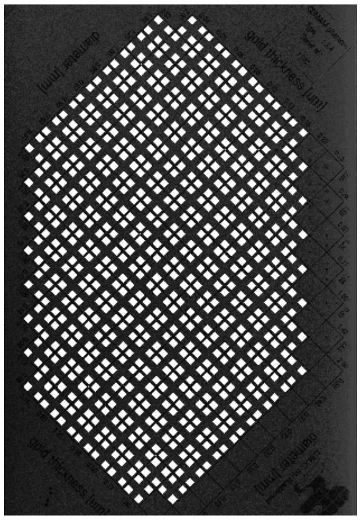

Fig. 3.

For both algorithms we have marked a “safe region” inside each cell where we can process the image without disturbing the grid itself. The cell shape is trapezoidal because of the geometry of the whole image acquisition system. In consequence we can not use the grid itself as rotation edge because each cell is not symmetrical with respect to their diagonals. To avoid this problem, we consider a square region inside each cell with a margin of 8 pixels from the upper crossing point toward the centre of the cell. The resulting square has a diagonal length of (D-16) pixels (where D= min. [left diagonal, right diagonal] pixels).

The first algorithm (“One rhombus”) rotates each cell in steps of 90 degrees around its centre. In the second algorithm (“Four of diamonds”), we define four little rhom-

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laptop computer, Dell Inspiron 4400, processor Intel Centrino Core2 Duo T7200, 2 Ghz, 2 Gb RAM.

buses inside each cell, centred each one at the four possible centres of the CDMAM's disks and then we interchange these rhombuses between them inside the same cell.

The interface for some combinations is showed in Fig. 4 and 5

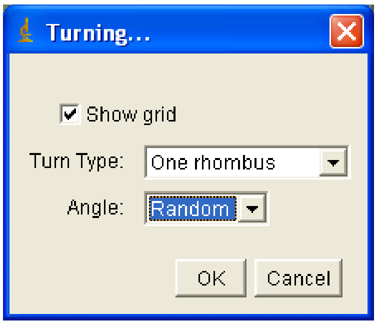

Fig. 4.

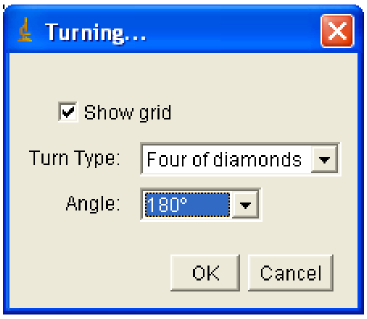

Fig. 5.

Both algorithms have some limitations:

a) The angle of the grid must lie between 35º and 55º, but these values simply are two parameters that can be changed easily.
b) The total image area should cover the total image area of the CDMAM with a tolerance less than a 10%. We will eliminate this limitation in the next program update.
c) There should not be great differences of uniformity inside each cell to be rotated. In this case, the program still works properly, but it is very easy to find out that the images are manipulated. We have defined two ROIs inside each cell (see Fig. 6 and 7). If the difference between the mean value of the pixels inside each ROI is greater than 2%, the manipulation is visible and this image could not use to run out our test. This limitation is a strong one related to the observer perception characteristics.

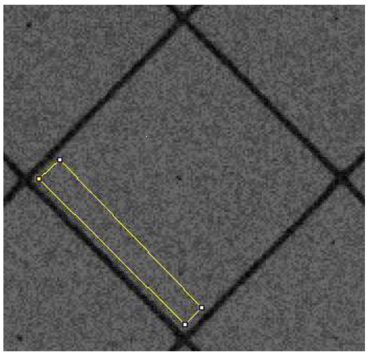

Fig. 6.

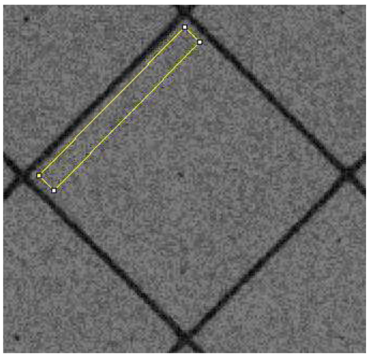

Fig. 7.

Algorithms evaluation. A ROC experiment has been developed to evaluate both algorithms. We arranged two set of images. Set #1 contained 8 different CDMAM images acquired under different radiological conditions. We obtained 8 modified images by applying algorithm “Rhombus” to each image. The complete set was formed with modified and non modified images randomly ordered. Set #2 was formed with the same 8 original CDMAM images and 8 modified images obtained by applying the algorithm “Four of diamonds”. The complete set was randomly ordered. The two sets of images were presented to two different groups of observers. The first one was composed by 27 medical physicists with an experience between 2 – 10 years in quality control. The second group was composed by 9 students of a Medical Physics Master, with no experience in diagnostic radiology neither quality control. Each observer had to answer to the question “Do you think this image has been computer modified in any form?” The test was run in different displays and the observers could use any tool of the ImageJ viewer with no time limits. The answer included a confidence level, from 0 to 4.

3. RESULTS

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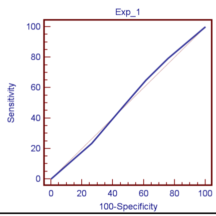
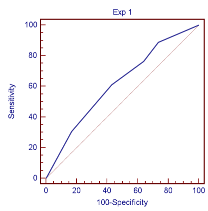
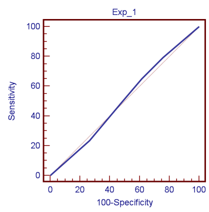
<tr><td>Experiment #1</td><td>
</td><td>
</td><td>
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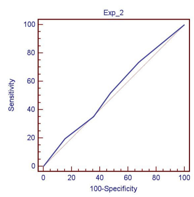
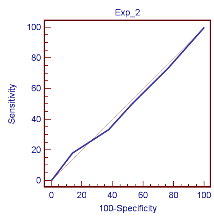
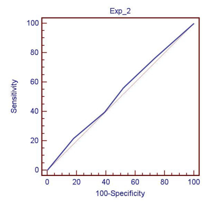
<tr><td>Experiment #2</td><td>
</td><td>
</td><td>
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Table 1.

As it can be seen from ROC curves in Table 1, the computer-modification of images was indistinguishable for both groups and for both algorithms. Result may show a light significance in test #1 analyzed for students, but the significance is at the limit of random choice. Combining expert and non-expert observers, the ROC area was 0.507±0.024 for first algorithm (significance level P=0.7724 for area 0.5) and 0.522±0.026 (significance level P=0.4003 for area 0.5) for the second one, indicating that there was no statistical difference between real and computer-modified images for both of algorithms presented.

4. DISCUSSION

The main finding of this study is that there are algorithms that can be used to modify CDMAM images, moving the disk positions around the centre of the cells. The modified image is indistinguishable, even for expert observers.

The strongest limitation of the algorithms is associated to images with a great lack of background uniformity inside the cells. Theoretically, this limitation could be removed by moving the image of the gold disk inside each cell. This approach presents some practical problems. The first one is related to the accuracy in cutting the disc image. This accuracy should be equal or better than two pixels around to avoid the annular section around the circle with a different gray level than the one at the destination point. The second one concerns to the change on the contrast ratio of the disk respect to the background in the destination point due to the lack of uniformity. This change would be produced although the cut operation had enough accuracy. Both problems might be solved changing the mean pixel value of the disk we move according the ratio of the back signal between the source and the destination point.

Our next steps are to optimize this software tool to manage images with a high gradient of uniformity and after that we will run the memory test with expert radiologists. Our developments will be regularly updated in the plugins section of ImageJ website.

5. CONCLUSION

1) Both algorithms can be used to manipulate CDMAM images.
2) They can be useful in those cases in which a researcher suspects that the observer is memorizing the position of some disks, mainly the critical ones around the middle section of the CDMAM.
3) They can be used to investigate and quantify the memory effect in the radiologist community. We have made a preliminary test with students, trying to train them to memorize the position of the disks, not for explicit methods, but for indirect ones.

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