Manual CDCOMV4 version 1.0: software for automated readout of CDMAM 4.0 images

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Contents

2 Introduction into CDCOMV4

This is a brief manual to help you start reading out your own digital CDMAM 4.0 images using our automated CDMAM 4.0 readout software (CDCOMV4).

2.1 *The CDMAM 4.0 phantom*

In mammography, the ability to visualize both very low contrasts and small details is crucial. The CDMAM 4.0 phantom (figure 1) was developed with the purpose of measuring and comparing threshold contrast visibility (visualized as contrast-detail curves) for mammography systems.

The CDMAM phantom was designed to derive contrast-detail visibility threshold information of mammography systems by conducting four alternative forced choice (4-AFC) experiments. The CDMAM 4.0 phantom contains 336 cells, with in each cell one centre and one corner gold disk with a specific diameter and thickness. The corner in which a disc is located varies between cells randomly. The combination of disc diameter and thickness is unique to each cell. The phantom has 21 different diameters each with its optimized gold disc thickness range.

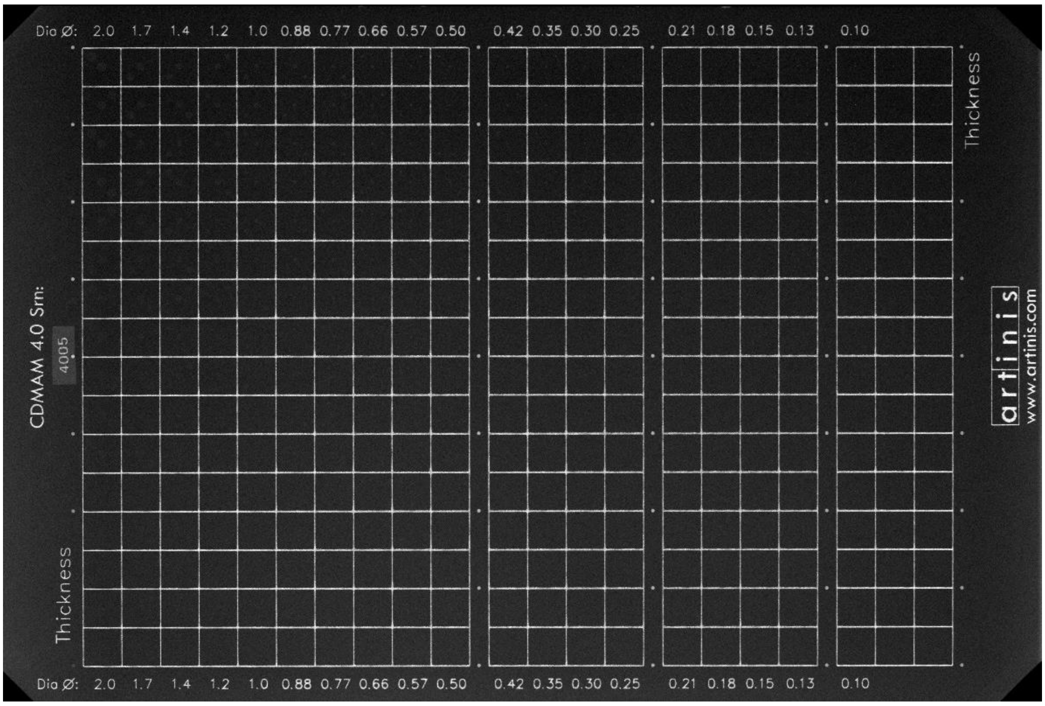

Figure 2.1. CDMAM 4.0 phantom.

2.2 *The purpose of CDCOMV4*

Reading out the CDMAM 4.0 phantom is a very labor-intensive task; it usually takes a human observer up to half an hour per image. CDCOMV4 was developed to automatically analyse the (computer) detectability of the gold disks in the CDMAM 4.0 phantom in a single image. This information can be useful for analyses in system acceptance tests of digital mammography systems and for system stability or degradation tests.

CDCOMV4 is a software tool developed to automate the tasks of reading CDMAM version 4.0 phantom images and creating score sheets. CDCOM does not read CDMAM version 3.4

images. CDCOM does not aim at predicting human readout however, instead it tries to use the information present in the image more optimally to conduct a 4-AFC experiment. The results of CDCOM can therefore not be used directly in combination with contrast-detail visibility limits set for human observers.
The CDCOMV4 application is based on CDCOM for CDMAM 3.4 version 1.6, following the same procedure, but adapted for the CDMAM4.0 phantom.

3 CDCOM Analysis

The automated image analysis by CDCOM can be separated in five phases:

- Analysis of the DICOM header
- Transformation to standardized input
- Phantom position detection
- Phantom specific corrections
- Individual disc detections

3.1 Analysis of the DICOM header

CDCOM needs the following elements in the DICOM header to correctly assess the image:

- (0018,1164) Imager Pixel Spacing (used only as an initial estimator of image scale) if not present (0028,0030) Pixel Spacing will be used.
- (0028,0010) Rows
- (0028,0011) Column
- (0028,0100) Bits Allocated
- (0028,0101) Bits Stored
- (0028,1041) Pixel Intensity Relationship Sign (used to facilitate grid detection, can be overruled by manual selection).
  if not present (0028,0004) Photometric Interpretation will be used.
- (7fe0,0010) Pixel Data

3.2 Transformation to a standardized input

The images of the CDMAM phantom are read by CDCOM and are transformed to a standardized form: (1) the image is cropped to the image of the phantom, (2) the image is rotated to the standardized orientation and (3) the image is rescaled to a pixel size of 50 μm, when the photo pixel size is greater than 50μm. This step is performed to eliminate differences in the detection of discs within the search area for images with different pixel size (see section “Individual disc detection”). Secondly, the photo size is reduced to just contain the grid image. This is done by making a coarse detection to the grid image, and adjust the image size accordingly.

3.3 Phantom position detection

The phantom position detection is splitted into several steps. First the grid position is determined, secondary the reference disc positions are determined. This secondary step is necessary for very precise location of the gold discs, which have diameters much smaller than the width of the grid lines. The grid detection make use of a Hough transform that is performed on a reduced resolution of 200 μm per pixel, allowing the position of the gridlines to be detected as two sets of equidistant maxima in Euclidian space. The cell corners are calculated as the points where two gridlines intersect. Next the locations of the corners of each cell are determined more accurately by applying template matching to the area around the approximate locations of each cell corner. In this procedure the template of the line crossing at the estimated position is correlated with the image data within a small area (51 by 51 pixels) around the predicted crossing. The location with highest cross correlation is the optimal location of the crossing. This step prevents image deformations (geometrical distortion), e.g. caused by a concave bucky shape, from influencing the results. No special template for the (partial) crossing at the boundaries are used, so this procedure might sometimes fail. Therefore a check on consistency of the final result is performed. If an outlying boundary crossing is found this is corrected by interpolation from surrounding points (Veldkamp 2003).

Using the grid position, the reference disc positions are determined, by searching for the maximum spot location on the predefined reference disc positions.

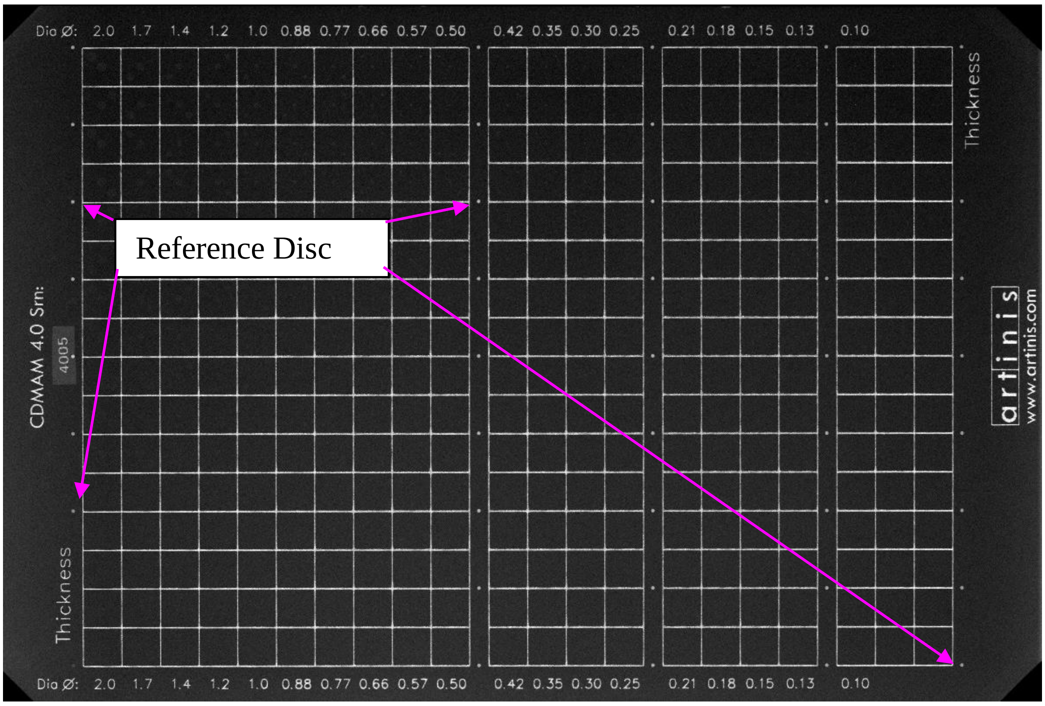

Figure 3.1. Reference discs

At a final step, the cell locations are corrected for small skew and sizing factors that might be present in the image. Also a possible cylindrical distortion due to the imaging method is corrected as needed.

3.4 Phantom and image specific corrections

CDCOM performs a 4-AFC experiment with an ideal observer model. It is based on the assumption that for each disc (with known diameter) there are four possible positions of which the possible locations are known exactly. In practical situations however, there will always be some inaccuracy in the determination of these positions (with influences for both human and computer observer) caused by the production process of the phantom, geometrical distortion of the phantom image and the limited resolution of the imaging system. Therefore CDCOM needs to deviate slightly by applying the model observer in a search region around each calculated (theoretical) position. It is crucial to understand that increasing the size of the search region will increase the influence of the image noise at the disc detection step, therefore increasing the search region will deteriorate the detection results especially for smaller diameters. In order to limit the influence of the noise specific to every individual image the disc search region has to be kept as small as possible, while avoiding the possibility of missing (part of) the disc under investigation. To prevent having to increase the search region an estimate of the phantom image specific translation, rotation and scaling is made by analyzing the position of all easily detectable center discs (large diameter and high contrast) using a relatively large search area of 500 µm. A template with the correct positions of all discs is rotated translated and scaled to match the easily detectable discs and calculated positions of all discs are obtained. Using a search area of 200 µm around the calculated disc positions, has proven to give reliable results (Visser, 2005).

3.5 Individual disc detection

Due to the phantom specific correction of the calculated disc positions the disc search area for individual disc detection can be limited to 200 micron around the calculated positions. Within this search area the location in which a disc of the specified size is most likely to be located is determined. This is done by finding the (by approximation) disc shaped area that has the lowest or highest (depending on the image properties) total pixel value, see figure A8.6a. In figure A8.6b the template is shown which is used to detect the circular discs on the phantom image. Due to the digital nature of the image the shape of the circle is approximated by the template. This approximation would not be equal for different pixel sizes and introduce differences in detection of the disc. Therefore the CDMAM image is rescaled to 50 µm pixel size

The average value of the pixels of the four locations are then compared to decide which corner is most likely containing the gold disc by determining the corner with the highest (or lowest, in case of pixel values decreasing with higher object density) pixel value. If the corner selected is the corner actually containing the disc, CDCOM has correctly detected the disc, otherwise it failed to detect it. This process is repeated for the centre disc together with the three corners not containing a disc in order to retrieve a second phantom image reading.

4 What does CDCOMV4 not do?

- CDCOMV4 does not combine the results for multiple CDMAM 4.0 images
- CDCOMV4 does not estimate the 62.5% detection rate points[4,5] for each disk diameter
- CDCOMV4 does not fit a psychometric curve through the 62.5% points[4,5]

5 Suggestions

It is advisable to combine the results of (at least) eight CDMAM 4.0 images. The CDMAM 4.0 phantom should be repositioned for each image to vary the positioning of the smaller disks with respect to the detector elements and to get information on the likelihood of correct detection for each individual cell. A method for combining the results of multiple images has been described by N. Karssemeijer and W.J.H. Veldkamp [4,5]

The CDCOMV4 program scores significantly better than the average human observer, therefore results from the CDCOMV4 readout software should not be used directly in combination with the limits for threshold contrast visibility for human observers.

6 Getting started

This section briefly explains how CDCOMV4 is used and what output is generated by the program.

6.1 Requirements

To be able to use CDCOMV4 you will need:

- a computer with a Windows operating system
- the most recent version of CDCOMV4 (download it from www.euref.org)
- CDMAM 4.0 phantom[1,2] images in DICOM format

6.2 Basic instructions

The CDCOMV4 software should be started from a command prompt using the command:

CDCOMV4 imagename [direction]

Where *direction* is the direction in which the image should be rotated (90°) to get the CDMAM image oriented like in Figure 2.1. Possible rotations are:

c - for clockwise rotation
cc - for counter clockwise rotation [default]
no - no rotation required

7 Program output

7.1 Image and debugging information

The first part of the program output contains information about the program, the image loaded and internal results which can be useful in case the program fails.

```
cdcom v4.1.0 (June 6, 2015)
Radboud University Nijmegen Medical Centre
uses DCMTK v3.6.0 2011-01-06


Load file MG1

pixelsize = 87 micron

- Rotating image
- Scaling image to 50 micron
- Selected pixel_value range: 1530 - 2513

 Determining grid position
 - initial values
   x0: -214.8    y0:  151.4    angle0:   0.00    scale0: 102.62
 - estimating phantom specific geometrical correction parameters
t = 1
 cell   15   20: 196.350931
```

The second part of the output contains the actual detection results. The first results are for the corner disks, the latter for the centre disks. Incorrectly detected disks are marked with the letter ’F’

```
Detection pass 1

 Diameters
 All    : 0.798
 2.00 - 0.40 : 0.836
 0.31 - 0.06 : 0.774


 All    : 0.798

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 . . . . . . . . F . . . . . . . . . . . .
 . . F . . . F . . . . . . . . . . . . F .
 . . . . . . . . . . . . . . . . . . . . .
 . . . F . . . . . . . . F . . . . . . . .
 . . . . . . . F . . . . . . . F . . . . .
 . . . F . . . . . . F F . F . F . . . . .
 . . . . . . . . F F . . F . . . . . . . .
 F . . F . F . F . F F F . F . F . . . . .
 . . F . . . . . . . . . F F F F F . . F .
 F . . F . . . . F . F . . F F . F F . F .
 . . F . F . F . . . F . . F . F F . F F .
 . F . F F F . . . F . F F F F . . F . . F
 . . . F . . . F . . . . . . F . F . F F F

 Detection pass 2

 Diameters
 All    : 0.801
 2.00 - 0.40 : 0.852
 0.31 - 0.06 : 0.769


 All    : 0.801

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 . . . . . . . F . . . . . . . . . . . . .
 . . . . . . . . . F . . F . . . . . . . .
 . . . . . . . . . . F F . . . . . . . . .
 . . . . F . . . . F . F F . . . . . . F F
 . . . F F . . . . F F F F F F . . . . . .
 . F . . . F . . F F . . . F . . . . . F .
 . . . . F . . . F . . . F F F . . F . F .
 . . F . F F F . . F F . F F F F F . F . .
 . . . F F F . F . . F . F . F . . F . F F
 F . . F F . F . . F F . F F . . . . F . F
```

8 Output files

CDCOMV4 creates two output files that may be useful for users that would like to combine the CDCOMV4 results for several images: matrix.inp and matrix2.inp. These files respectively contain the detection results for the corner disk detection and the centre disk detection steps.

	Diameter (mm)																				
	2	1.7	1.4	1.2	1	0.88	0.77	0.66	0.57	0.5	0.42	0.35	0.3	0.25	0.21	0.18	0.15	0.13	0.1	0.09	0.08
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1
6	1	1	1	2	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	1
7	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1	2
9	1	1	1	1	2	1	1	1	2	1	2	1	1	2	1	1	1	1	1	1	2
10	1	1	2	1	1	1	1	1	1	2	1	2	1	1	2	1	2	2	1	1	1
11	1	1	2	2	1	1	2	2	2	2	2	2	1	1	1	1	1	1	1	2	1
12	2	2	1	2	1	2	1	1	1	2	2	1	2	2	1	2	1	1	1	1	1
13	2	2	1	2	1	1	2	2	1	2	2	1	2	2	2	2	1	1	1	1	1
14	1	1	1	2	2	1	1	1	2	1	2	1	1	2	1	2	2	2	1	2	1
15	1	1	2	1	1	1	2	2	1	2	2	1	2	1	2	2	1	2	2	2	1
16	1	2	2	2	1	2	2	1	1	2	1	2	2	1	2	1	2	2	2	1	1

In this output 1 is a correctly detected disk and 2 is an incorrectly detected disk.

9 Troubleshooting

These are some of the most common problems and possible solutions.

P: CDCOMV4 only detects about 25% of the disks, randomly spread over the image. CDCOMV4 was not able to detect the grid (number of corrected border errors > 100)

S: This has been observed for some images for which the DICOM header did not contain the correct value for the Pixel Intensity Relationship Sign, which indicates whether the pixel value increases or decreases for increasing x-ray intensity. If it is not present in the DICOM header CDCOMV4 v1. 5. 2 uses Photometric Interpretation instead.

P: CDCOMV4 only detects about 25% of the disks, randomly spread over the image, but the grid was detected (number of corrected border errors < 100)

S: This can probably be solved by rotating the image the other way around by using the command:

CDCOMV4 imagename c

instead of

CDCOMV4 imagename [cc]

P: How do I use the results of CDCOMV4?

S: In the Supplement to the European Guidelines fourth version, the articles by Karssemeijer and Veldkamp[4,5] methods are described to combine the results for multiple CDMAM images into a contrast-detail curve.

10 References

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