Teknisk dokument ▪ 4

Analysis of the uniformity of mammography detectors

Evaluation of a proposed method and a new software tool for use in routine quality control

Statens strålevern
Norwegian Radiation Protection Authority

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Ana María Acosta Roa

Kristin Pedersen

Silje Flatabø

Gisella Gennaro

Statens strålevern

Norwegian Radiation
Protection Authority
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Abstract:
Test of newly developed software for analysis of detector uniformity in digital mammography, and suggestion of appropriate limiting values.

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Mammografi, digital detektor, kvalitetskontroll.

Resymé:
Utprøving av nylig utviklet programvare for analyse av detektoruniformitet i digital mammografi. Forslag til passende grenseverdier.

Head of project: Kristin Pedersen.

Approved:

Hanne Kofstadmoen, director, Department of Radiation Applications

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Norwegian Radiation Protection Authority, P.O. Box 55, N-1332 Østerås, Norway
Telephone +47 67 16 25 0
E-mail: nrpa@nrpa.no
www.nrpa.no

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1 Introduction

The Norwegian Radiation Protection Authority (NRPA) is responsible for the annual status control of all mammography machines participating in the Norwegian Breast Cancer Screening Program (NBCSP). One important test is the analysis of detector uniformity. This test provides valuable information about the status of the detector in terms of signal non-uniformity and dead pixels. It can also help to reveal the presence of artifacts.

In 2010, NRPA standardized their methodology for annual quality controls of mammography equipment [1], and adopted the detector homogeneity test described in the European guidelines for quality assurance in breast cancer screening and diagnosis [2]. Recently, a working group has been formed within the European Federation of Medical Physics (EFOMP) with the purpose of writing a modern and comprehensive test protocol for digital mammography. For some of the test procedures, special software has been developed to analyze the resulting test images. Among the suggested test procedures accompanied by suitable software, there is a test of the detector uniformity.

The purpose of this work was twofold:

1. To test the newly developed software from the EFOMP working group by analyzing the most recent uniformity test image from a majority of the mammography systems in the NBCSP.
2. To suggest appropriate limiting values for the proposed uniformity test.

Only direct digital radiography (DDR) systems were included in this study.

2 Materials and Methods

Uniformity images from each of the 53 mammography systems in the NBCSP were considered in this study. These images had been acquired during previous quality control visits by medical physicists, as described in the following subsection. The system models included were: GE Senographe DS, GE Senographe Essential, Siemens Mammomat Inspiration, Siemens Mammomat Novation, Sectra MDM L30, Hologic Selenia, and Hologic Dimensions.

2.1 Image acquisition

For the uniformity test, a uniform slab of Perspex (thickness 25, 40, or 45 mm), covering the entire field of view of the detector, as shown in Figure 1, was subjected to several exposures. The initial exposure was done with the system in automatic mode. For the subsequent test images, normally three, the target, filter and kV were set manually to the values chosen by the system for the first exposure, along with a mAs value which was also set as close as possible to the value chosen automatically.

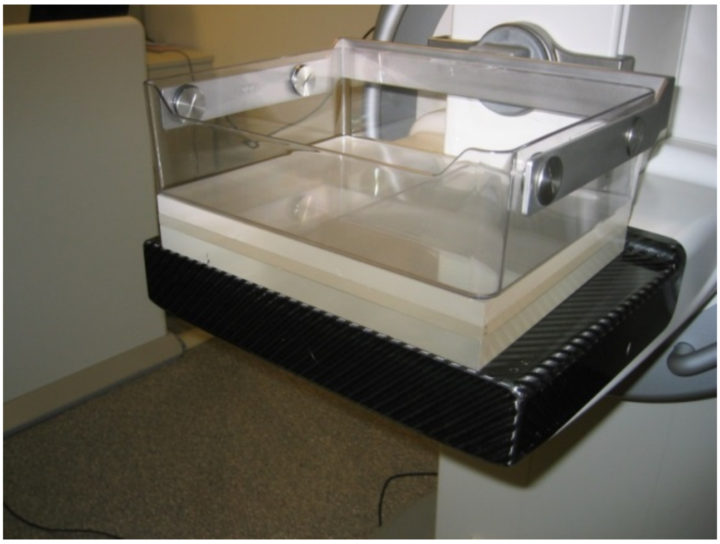

Figure 1 *Image acquisition set-up: Perspex phantom covering the detector is subjected to x-ray exposures.*

2.2 Image analysis

The image analysis was effectuated by using EFOMP's recently developed software. A screenshot showing the interface of this software is presented in Figure 2. The software allows the user to either analyze the uniformity in the whole image, or to select the region of the image to be examined by using drawing tools. This feature makes it particularly easy to crop the edges in images where, e.g., the phantom does not cover the whole detector; or to avoid any known non-active parts of the detector. In order to analyze the image, the user must define the size of quadratic regions of interest (ROIs) which divide the image into a matrix of elements, $ROI_{i,j}$, this is illustrated in Figure 3. The software then yields the local and global uniformity values of an image, as described below.

The local uniformity (LU) is determined by calculating the local difference between the Mean Pixel Value ($MPV_{i,j}$) in each adjacent ROI and the average across the eight neighbouring ROI's, $MPV_{neighbour}$:

$$\mathrm{LU} = \max\left(\frac{\left|\mathrm{MPV}_{i,j} - \mathrm{MPV}_{neighbour}\right|}{\mathrm{MPV}_{neighbour}}\right)$$

Due to this condition, the method does not calculate the uniformity in the entire image, but leaves an outer edge with a width of approximately a half of a ROI uncalculated.

The global uniformity (GU) is calculated as the maximum deviation between $MPV_{i.j}$ and the mean pixel value measured from the entire image, MPV_{image}:

$$\mathrm{GU} = \max\left(\frac{\left|\mathrm{MPV}_{i,j} - \mathrm{MPV}_{image}\right|}{\mathrm{MPV}_{image}}\right)$$

The method returns the number of ROIs that deviate more than the given limit percentages from the $MPV_{neighbour}$ and the MPV_{image}, together with the maximum deviation.

In addition to testing the new software, the main scope of this study was to investigate the level of the maximum deviation of the LU and GU obtained for different mammography systems, in order to suggest reasonable levels for limiting values.

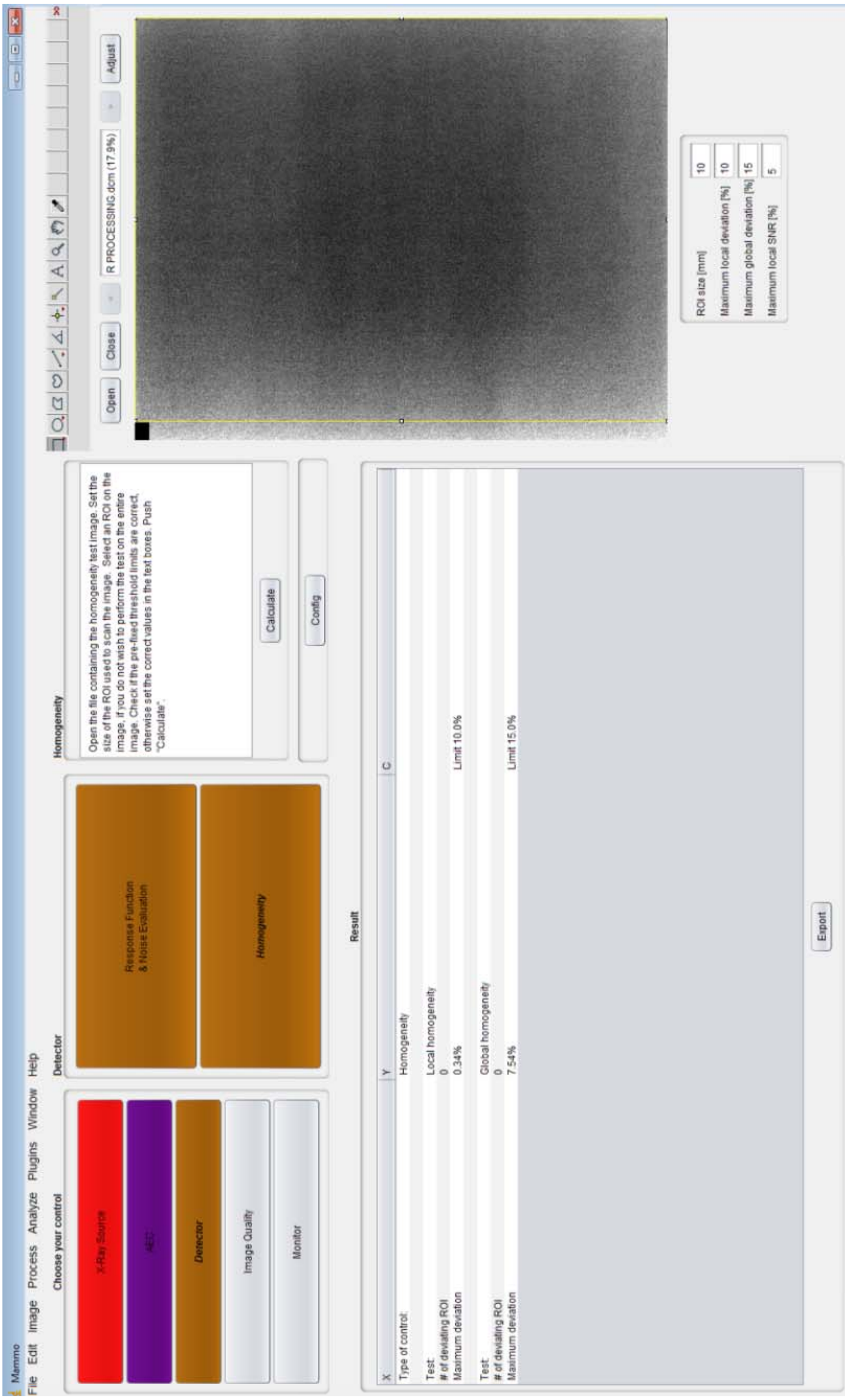

Figure 2 *Screenshot of the software for image analysis developed by the EFOMP group. The image to be analyzed appears on the right and in this case was cropped in order to exclude the inactive square in one corner.*

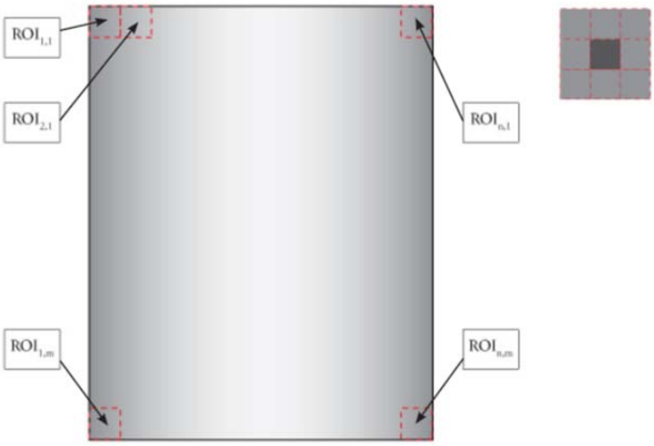

Figure 3 *Illustration of naming convention for ROIs. The image is divided into a matrix of quadratic elements $ROI_{i,j}$, each with a middle pixel value $MPV_{i,j}$. A single ROI together with its eight neighbouring ROIs are represented on the upper right side of the image.*

3 Results

The results of the analyses are presented in Figure 4. This figure shows that the maximum deviation in local uniformity (LU, diamond shape indicators) remained below 1 % for all the considered systems. The maximum deviation in global uniformity (GU, circular indicators), on the other hand, ranged from below 1 % to nearly 10 %, with the majority of systems showing a maximum deviation below 5 %. There were variations from one system to another, both within the same and for different vendors. The lowest variation in GU was observed for the seven GE DS systems, which all showed GU values well below 2%. On the other hand, four of the eleven GE Essential systems displayed the highest deviation from GU, up to almost 10%.

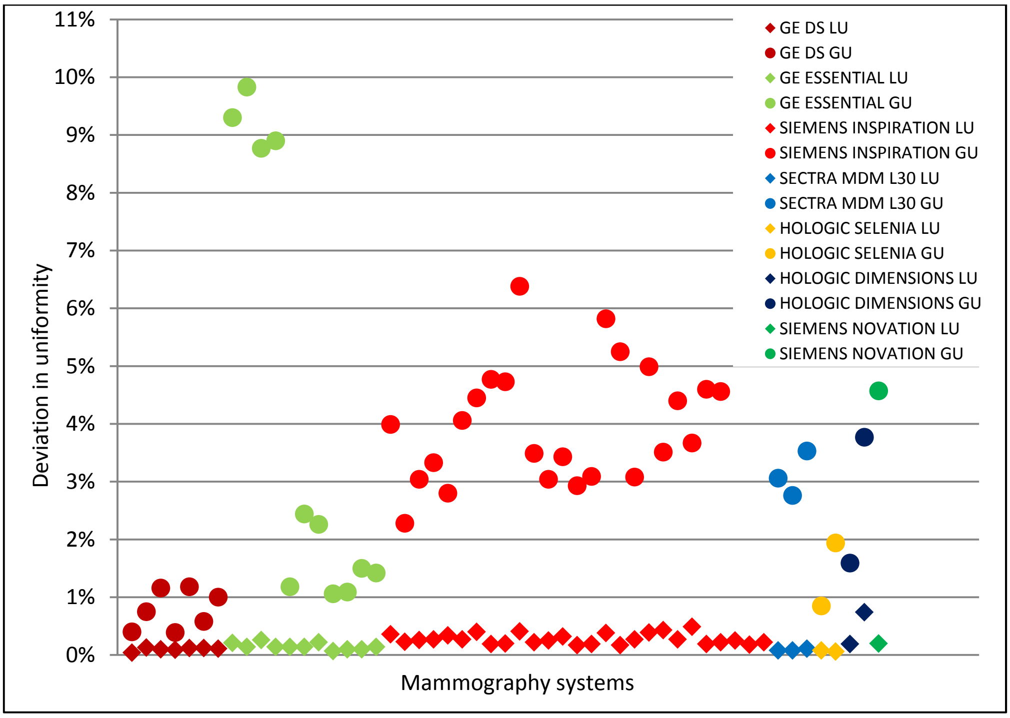

Figure 4. *Deviations in LU (diamond shape indicators) and GU (circular indicators) for uniformity images from the 53 mammography systems included in this study.*

4 Discussion

Testing the uniformity of a detector by imaging a homogeneous phantom is an important method to determine if the detector shows any irregularities. A test of this kind will therefore remain a key element of the quality control of mammography systems. The software developed by the EFOMP group provides us with an alternative tool to examine the uniformity of an image, where in addition to obtaining the deviation from the MPV in the whole image, it is possible to investigate local changes which may not appear visible to the eye, but which still could reveal the presence of non-uniformities or damage to the detector.

Difference in phantom thickness was seen to be one reason for the observed wide range in results for the Global Uniformity. Potential other reasons needs to be investigated further. Factors that might play a role include detector type, calibration thickness, and dose level.

5 Conclusion

The software tool performed as expected and was easy to use. For local uniformity, LU, the results were very similar for all systems included in the study. The results indicate that the limiting value for DR systems can be set as low as 1 %. The maximum deviation in global uniformity, GU, was at a higher level and showed larger variation. The reason for this need to be investigated further before a final decision is made regarding the limiting value for this parameter.

6 References

1. European Guidelines for Mammography Screening and Diagnosis (4th ed., 2006). European Commission. Office for Official Publications of the European Communities, Luxembourg.
2. Pedersen K, Bredhold K, Landmark ID, Istad TSJ, Almén A, Hauge IHR. Teknisk kvalitetskontroll – statuskontroller for digitale mammografisystemer. StrålevernRapport 2010:08. Statens strålevern, Østerås 2010.

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