IMAGE QUALITY ANALYSIS OF DIGITAL MAMMOGRAPHIC EQUIPMENTS

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Abstract. The image quality assessment of a radiographic phantom image is one of the fundamental points in a complete quality control programme. The good functioning result of all the process must be an image with an appropriate quality to carry out a suitable diagnostic. Nowadays, the digital radiographic equipments are replacing the traditional film-screen equipments and it is necessary to update the parameters to guarantee the quality of the process. Contrast-detail phantoms are applied to digital radiography to study the threshold contrast-detail sensitivity at operation conditions of the equipment. The phantom that is studied in this work is CDMAM 3.4, which facilitates the evaluation of image contrast and detail resolution.
One of the most extended indexes to measure the image quality in an objective way is the Image Quality Figure (IQF). This parameter is useful to calculate the image quality taking into account the contrast and detail resolution of the image analysed. The contrast-detail curve is useful as a measure of the image quality too, because it is a graphical representation in which the hole thickness and diameter are plotted for each contrast-detail combination detected in the radiographic image of the phantom. It is useful for the comparison of the functioning of different radiographic image systems, for phantom images under the same exposition conditions.
The aim of this work is to study the image quality of different images contrast-detail phantom CDMAM 3.4, carrying out the automatic detection of the contrast-detail combination and to establish a parameter which characterize in an objective way the mammographic image quality. This is useful to compare images obtained at different digital mammographic equipments to study the functioning of the equipments.

Keywords - Digital processing, mammographic phantom, image quality

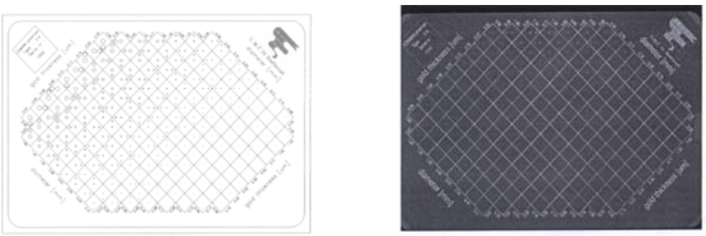
1. Introduction

In a quality control of the radiographic equipment, the quality of the obtained image is very useful to characterize the physical properties of the imaging chain. In the radiographic technique it is necessary that objects with low contrast and diameter could be distinguish of its background, to carry out a suitable diagnosis [1]. The use of digital systems allows the automatic analysis of the obtained radiographic images, increasing the objectivity in the evaluation of the image

Nowadays the mammographic screening programmes functioning in many developed countries are the most efficient method in preventing and detecting breast cancer. This programmes carry out the acquisition of a high number of mammographies, each one of them is evaluated by a radiologist [2]. This reason together with the digital technologies, as for the image treatment as for the storage of these ones in digital format, has driven the development of techniques to carry out an automatic analysis of these mammographies [3]. These techniques have in common that they work with the digital image and stands out the details of the image, which is important to study the image quality in an objective way.

The phantom used in this work is the CDMAM 3.4 [4] which consists of an aluminium base with gold disks of various thickness and diameters, which is attached to a plexiglas cover. The gold disks range in diameter from 0.06 to 2.0 mm and in thickness from 0.03 to 2.0 µm, resulting in a radiation contrast range of 0.5-30% at standard mammography exposure conditions. The phantom is used with 4 plexiglass plates, each with a thickness of 10 mm. The dimensions of the phantom and plexiglass plates match the standard mammography film size, that is 180 mm x 240 mm. The disks are located in a matrix of 16 rows and 16 columns. The matrix is rotated forty-five degrees to minimize influences of the heel effect that causes optical density variations.

Within a row the disk diameter is constant with exponentially increasing thickness from 0.03 to 2.00 µm and within a column the disk thickness is constant, with exponentially increasing diameter from 0.06 to 2.0 mm. The phantom, at the first rows has only central disk, while in the other rows there are two identical disks, one in the centre and one in a random chosen corner as it is shown in Figure 1.



(a) (b)

Figura 1: (a) Sketch of the phantom CDMAM 3.4 (b) Radiographic image of the CDMAM3.4

2. Image quality

Image quality index

There are various parameters to measure the quality of the radiographic image. One of the most extended to measure the quality in an objective way is the Image Quality Figure (IQF), that is defined in that way:

$$IQF = \sum_{i=1}^{n^o cols} C_i \cdot D_{i,\min}$$

where $D_{i,th}$ is the threshold diameter in the contrast column i and C_i is the value of the thickness of the holes of the column. The sum is extended for all columns of different thickness. In addition two rules are applied, when one column is completely invisible, it is punctuated with a diameter $D_{i,th}$ of 2.5 mm (for a gold disk thickness between 0.03 and 0.25 µm). And when one column is completely *visible, it is punctuated with a diameter $D_{i,th}$ of 0.06 mm (for a gold disk thickness between 0.16 and 2.00 µm.)*

Because the image quality increases when the correctly identified contrast-detail combination has a smaller depth and diameter, it is defined IQF_{inv} that gives an increasing value for increasing image quality.

$$IQF_{inv} = \frac{1}{\sum_{i=1}^{n^o cols} C_i \cdot D_{i,\min}} \cdot 100 = \frac{100}{IQF}$$

Contrast detail curve

The contrast-detail curve is a graphical representation in which the hole thickness and diameter are plotted for each contrast-detail combination detected in the radiographic image of the phantom. It is useful for the comparison of the functioning of different radiographic image systems, for phantom images under the same exposition conditions. The better image system produces images that allow the detection of lower contrasts and details.

3. Methodology

The radiograhic image obtained of CDMAM 3.4, must be evaluated in the area where the holes are detected, by indication of the location where the non central holes are seen. In this work, we have used the software CDCOM [5], developed by the Radiology Department of the University Medical Centre Nijmegen to automatically evaluate the images of the CDMAM 3.4 phantom.

The evaluation of the radiographic image quality by this software is done in several steps: First of all, the algorithm determines the border of the phantom, resolve its position and the centre of its contrast-detail combinations by the Hough transform (Figure 2). After that, it is determined the mean and standard deviation of the background and the mean and standard deviation of the spot that is the projection of the disk in each contrast detail combination. The program tests with a statistical method, if the average contrast-detail is greater than the average background, to consider the combination as detected. Then, it is applied a score correction taking into account the 4 nearest neighbours of the combination under evaluation (for the combinations at the edges of the phantom and for the absent corners (0.03 µm/2.0 mm y 2.00 µm/0.06 mm) only takes into account its both nearest neighbours). Then, the program shows two graphics one for the corner other for the central contrast detail combinations. The uncorrected contrast detail combinations are marked with F, as it is shown in Figure 3. Finally, the IQF_{inv} is calculated and the contrast-detail curve obtained.

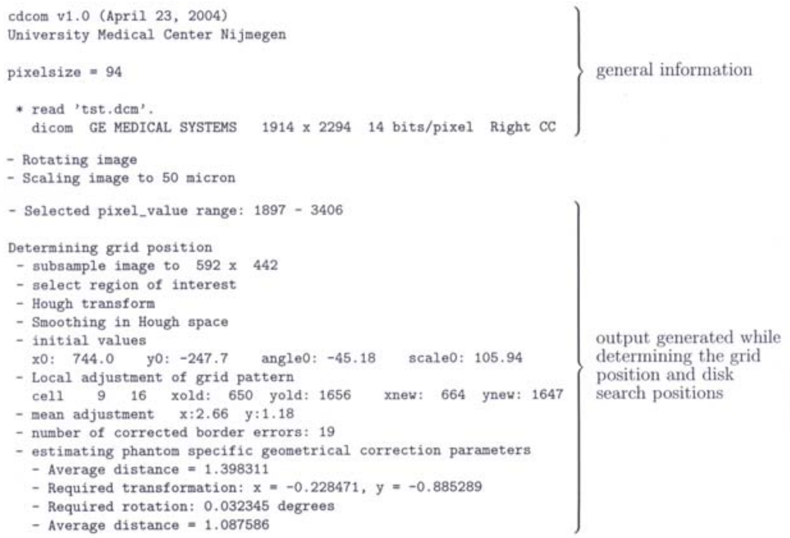


Figure 2: Output of the CDCOM program, with the border lines detected.

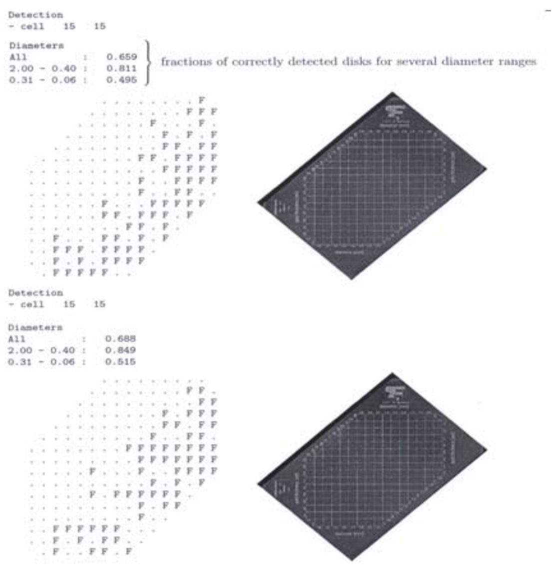


Figure 3: Results of the corner and central contrast detail combinations.

We have obtained some radiographic images, at two different technology mammographic systems. Two of them are computed radiography and the other two direct radiographic digital. The images have been obtained in dicom format and at different radiographic techniques.

We have studied some units of the Valencian Breast Cancer Screening Programme, which recently have incorporated digital mammographic equipments of computerised radiography and direct radiography. The mammograhic digital image acquisition is in dicom format 3.0, which is the format that is actually implemented in medical image communication. It is a protocol developed by ACR-NEMA en 1993 of acquisition and transmission of medical images [6].

The phantom has been studied with two plexiglass tablets above and under of it, to simulate the breast typical thickness. The acquisition of the images are carried out in different conditions for each unit and varying the functioning parameters of the mammographic equipment of kv, mAs and AEC. The images have been obtained without preprocessing with thick size of the focus, anti scatter grid and compression plate. After that, the image is evaluated with the programme CDCOM and the quality of the image obtained with the contrast detail curve and the image quality figure.

The mammography equipments used are the following:
Computed radiography (CR):
Unit 1
Senographe DMR, anode of Mo with filter of Mo 30µm; Fuji Profet CS

Unit 2
MammoDiagnostic UC Philips, anode of Mo with filter Mo 30µm; Agfa CR 75.0

Direct radiography (DR)
Unit 3
Mammomat Novation Siemens DR, anode of Mo with filter Mo 30µm

Unit 4
Senographe 2000 D General Electric DR, anode of Mo with filter Mo/Rh 30µm.

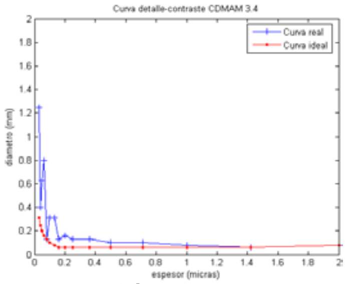
This unit has an equipment which has three different automatic modes of working, which are: STD that is the standard mode, CNT that is the contrast mode decreasing kv and increasing mAs) and DOSE, which is the mode where the dose is lower but the contrast decreases because kv increase and mAs decereases.

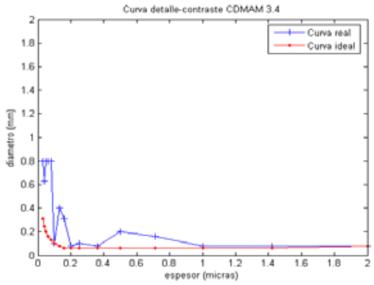
Unit 5
DM 1000 (Agfa) DR, anode of Mo with filter Mo/Rh 30µm.

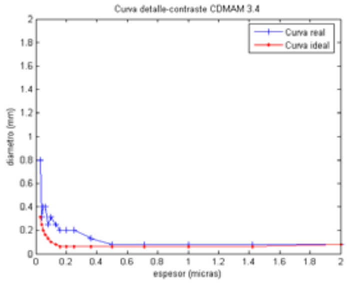
4. Results

The results of the image analysis obtained of the computerized and direct mammography equipments under study are the following. In the contrast-detail curves is drown in blue the real curve obtained for the image in that conditions, and for comparison is drown in red an ideal system in which all the minimum diameter objects would be detected.

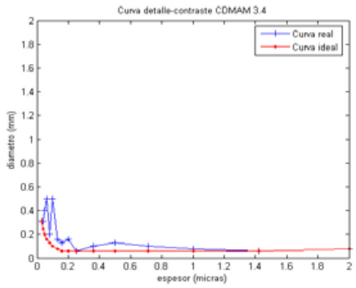
Unit 1:

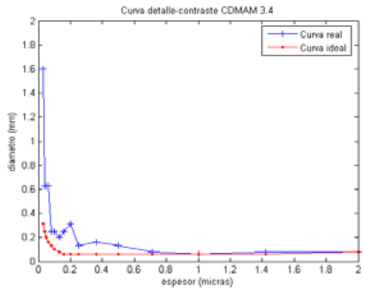






26 kv, CAE+0, 101 mAs　　*28kv, CAE: -2, 40 mAs,*　　*28 kv, CAE: +0, 55 mAs,*



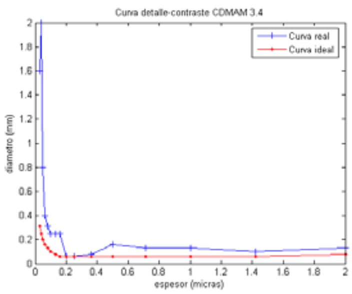


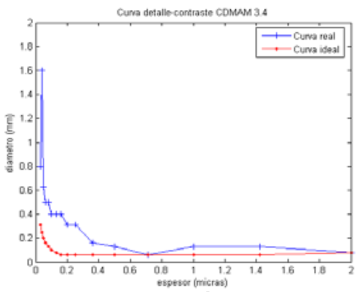
28kv, CAE: +2, 75 mAs　　*30 kv, CAE:+0, 32 mAs*

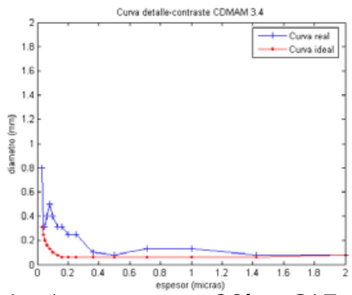
Images			IQI_{inv}
kV	CAE	mAs	
26	+0	101	126.10
28	-2	40	105.28
28	+0	55	127.70
28	+2	75	138.22
30	+0	32	116.14

Table 1: Results of the IQI_{inv} for the images in different conditions.

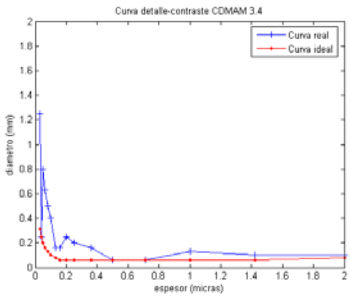
Unit 2:

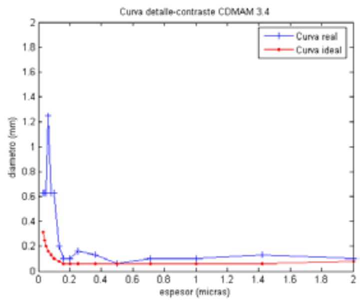






26 kv, CAE: +0, 117mAs　　*28kv, CAE:-2, 54 mAs*　　*28kv, CAE: +0, 76 mAs*



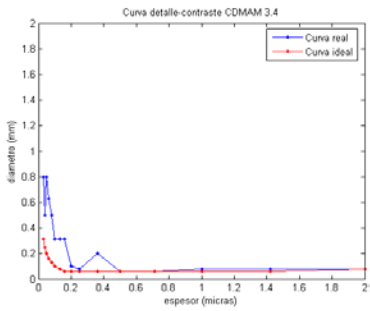


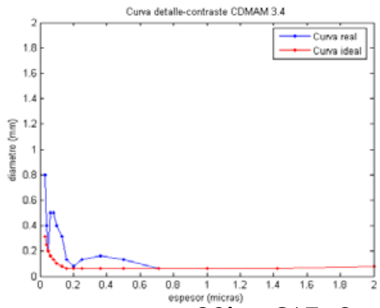
28kv, CAE:+2, 104 mAs *30kv, CAE: +0, 47 mAs*

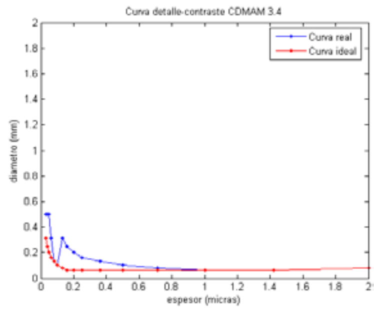
Images			IQI_{inv}
kV	CAE	mAs	
26	+0	117	110.49
28	-2	54	91.26
28	+0	76	108.09
28	+2	104	105.69
30	+0	47	95.16

Table 2: Results of the IQI_{inv} for the images in different conditions.

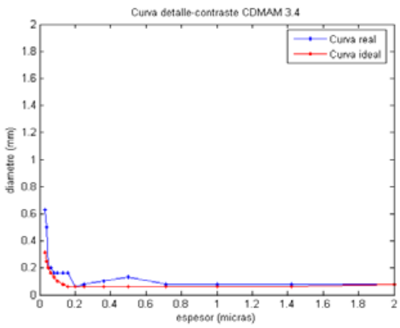
Unit 3:

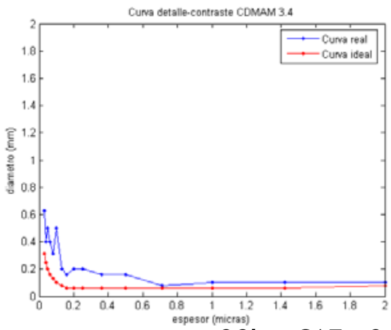






26kv, CAE: +0, 139mAs *28kv, CAE:-2, 71mAs* *28kv, CAE: +0, 91.1mA*





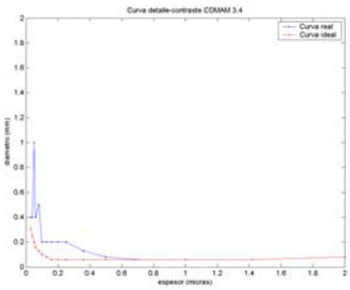
28kv, CAE: +2, 110mAs *30kv, CAE:+0, 58.4mAs*

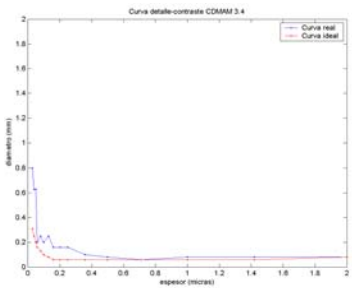
Images			IQI_{inv}
kV	CAE	mAs	
26	+0	139	121.82
28	-2	71	135.14
28	+0	91	139.26

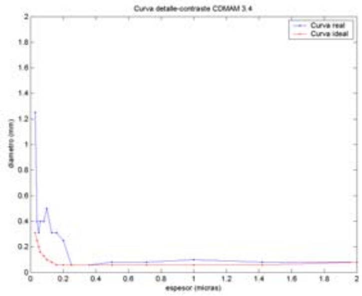
28	+2	110	147.17
30	+0	58	106.76

Table 3: Results of the IQI_{inv} for the images in different conditions.

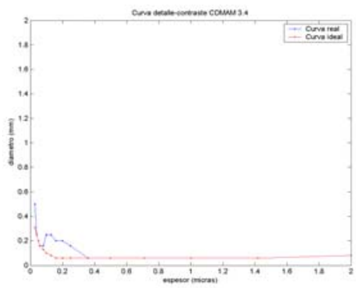
Unit 4:

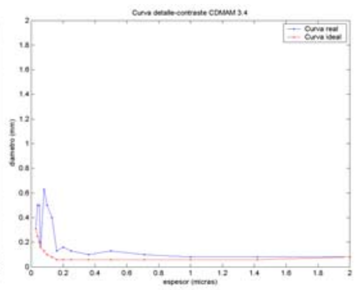


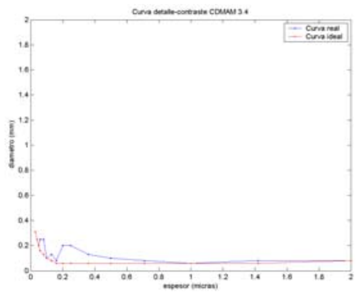




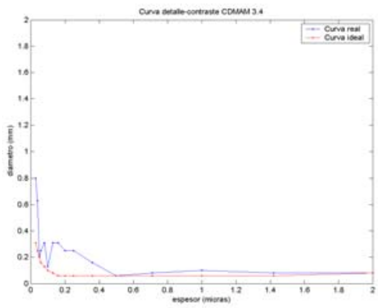
STD 28kv, 63mAs *CNT 26kv, 132 mAs* *DOSE 31kv, 35mAs*

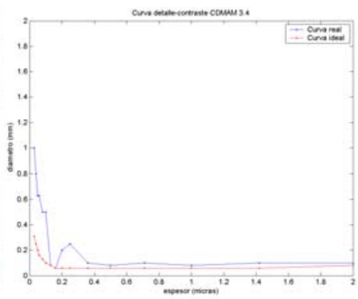


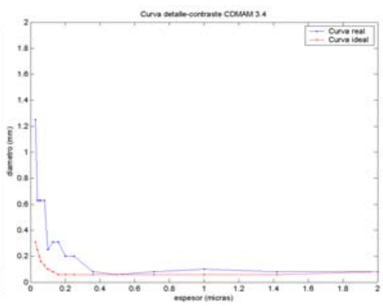




26kv, CAE:+0, 160 mA, *26kv, CAE:+0, 100 mAs* *28kv, CAE:+0, 80 mAs*







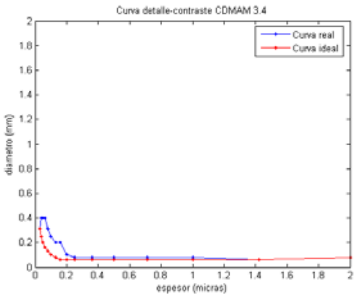
28kv, CAE:+0, 50 mAs *31kv, CAE:+0, 45 mAs* *31 kv, CAE:+0, 28 mAs*

Images			IQI_{inv}
kV	CAE	mAs	
28	STD	63	134.30
26	CNT	132	136.05
31	DOSE	35	121.67
28	+0	80	146.80
28	+0	50	120.13
26	+0	160	159.67
26	+0	100	120.89
31	+0	45	109.55

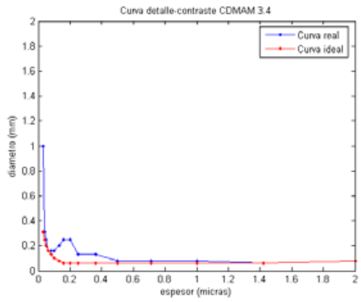
31	+0	28	114.09

Table 4: Results of the IQI_{inv} for the images in different conditions.

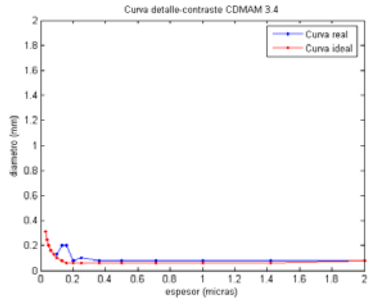
Unit 5:



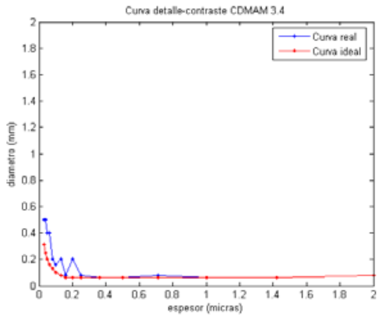
26kv, CAE:+0, 142.9mAs



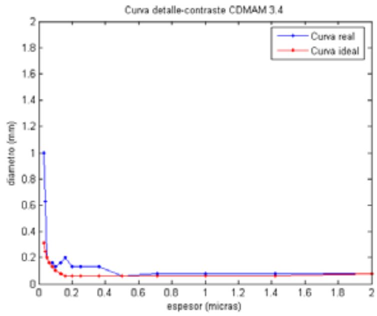
28kv,CAE:-2, 62.8mAs



28kv, CAE:+0, 86.5mAs



28kv, CAE:+2, 109mAs



30kv, CAE:+0, 56.8mAs

Images			IQI_{inv}
kV	CAE	mAs	
26	+0	142.9	149.72
28	-2	62.8	140.73
28	+0	86.5	156.13
28	+2	109	160.41
30	+0	56.8	143.04

Table 5: Results of the IQI_{inv} for the images in different conditions.

5. Conclusions

As it can be seen from the results above, the value of IQF_{inv} let the evaluation of the image quality of the digital equipments in an objective way. It is an useful index to study the image quality of the images and it varies with the different functioning conditions kv and mAs of the equipment. These variations are sensitive of this parameter to study the functioning of the equipment to complete the quality control of the equipment.

From the results we can see that the image parameters as the contrast detail curves of the DICOM images of the CDMAM 3.4 phantom and the Image Quality Figure (IQF) it is observed that the direct digital mammographic equipments have bigger indexes that indirect digital equipments, so it indicates that the image quality obtained with direct equipments is better than in the computed radiography. Comparing indirect mammographic equipments Unit 1 has better image quality than Unit 2, for similar radiographic techniques; comparing direct mammographic equipments the image quality parameters are bigger for Unit 5. These results have to be considered joined to the analysis of the dose. We are working to study some correlations between them.

6. Acknowledgements

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7. References

[1] Protocolo Español de Control de Calidad en Radiodiagnóstico. Revisión 1 (Aspectos Técnicos) ISBN:84-87450-70-9 (2002)

[2] Conselleria de Sanitat Monografies Sanitaries, Programa de Prevención de cáncer de mama en la Comunidad Valenciana, serie E25, 1998.

[3] Working Party of Radiologists, Quality Assurance Coordinating Group, Computer aided detection in mammography, NHSBSP Publication nº 48, (2001).

[4] Artinis Medical Systems B.V, User Manual CDMAM 3.4, 2002.

[5] Department of Radiology, University Medical Centre Nijmegen, CDCOM Manual:software for automated readout of CDMAM 3.4 images, 2004

[6] National Electrical Manufacturers Association, Digital Imaging and Communications in Medicine (DICOM), (2003).