QUALITY ASSURANCE APPLIED TO DIGITAL RADIOGRAPHIC EQUIPMENTS BY DEVELOPED SOFTWARE FOR PHANTOM IMAGES

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Abstract

The assessment and control of image quality is a fundamental task associated with good practice to guarantee a suitable diagnosis by the radiologist. The need for image quality assessments in radiography is well established and the use of test phantoms is a common method for this purpose. In this work we present a developed tool which consists of a specific phantom (named RACON) that is used for acceptance and constancy test in order to analyze the image obtained by digital radiographic equipment, software (named SoftRACON) for automated image analysis with digital processing techniques, and a database to store test phantom images and the scoring results.

The main objective is to characterize the constancy of the radiographic imaging chain and guarantee acceptable image quality, related to well-functioning of the radiographic equipment. Therefore, the application presented in this work is sensitive enough to the operating conditions of the radiographic digital equipment and allows the assessment of the imaging system quality and, consequently, increases the objectivity (accuracy) in the evaluation of the image.

Keywords: quality assurance, radiographic phantom, digital image

I. INTRODUCTION

Over the past few years, digital imaging radiographic systems have become available in clinical practice and are replacing conventional radiographic equipment in medical applications. The assessment and control of image quality is a fundamental task associated with good practice. The need for image quality assessment in radiography is well established [1,2] and the use of test phantoms is a common method for this purpose. Generally, test phantom assessment of image quality is subjective. It is difficult for technicians to maintain constant criteria for scoring phantom images and, different technicians might apply different visibility thresholds for phantom targets. In this context, one can appreciate the importance of the development of specifically designed test phantoms for digital imaging systems together with automated scoring methods (see, for instance, [3,4]). The automated image analysis method must produce more consistent results than human observer scores. As a result, the use of digital systems allows the automatic analysis of the obtained radiographic images, increasing the objectivity in the evaluation of the image.

In this work, we present a tool to study the image quality of digital radiographic equipment. The main objective is to characterize the constancy of the radiographic imaging chain and guarantee acceptable image quality. The facility presented for assessment and control of image quality consists of a test phantom (named RACON), specifically developed software (named SoftRACON) for automated image analysis and a database to store the test phantom images and the scoring results.

II. METHODOLOGY

II.A RACON Phantom

The RACON test phantom has been designed, following international recommendations [2], to perform acceptance and constancy test applied to radiographic equipments. The phantom is made of plexiglas square block of size 325x325x10 mm and contains several targets: low contrast objects varying in diameter and size for the threshold contrast resolution, high resolution test target for the limited spatial resolution, copper step wedge with different thickness for the evaluation of the dynamic range of the image system, homogeneity zone in which the mean gray level is related with the type of exposition and, finally, geometric alignment marks to measure position and size of radiation field. Moreover, an additional piece allows analyzing the X-ray beam orthogonality. Figure 1 shows a radiographic image of RACON phantom.

Figure 1: Radiographic image of RACON phantom.

II.B SoftRACON package

SoftRACON is a software package developed for automated analysis of images produced with the RACON phantom by digital radiographic imaging systems. The software has been designed specifically for this phantom and it is based on several digital image processing techniques adapted to analyze each phantom's target, as can be seen in previous work developed by the authors [3,5]. Software SoftRACON is based on the commercial language programming software MATLAB 7.0, implemented for friendly use with graphical interface as it is mentioned in [5].

The image analysis process with the SoftRACON analyzer can be summarized as follows:

1. The digital phantom image is captured by the computer program.
2. The program searches for the representative geometrical marks in the image and, using these marks, it obtains subimages of each test target.
3. Specific algorithms are applied to each subimage, these are based on digital image processing techniques such as denoising filters for noise removal, pattern recognition, edge detectors, thresholding and morphological operators to detect each test.
4. The analysis of each test zone of the phantom includes the measurement of several image properties such as detected number of low contrast-detail combinations and contrast-detail curve, high frequency resolution limit, step wedge dynamic range, and geometrical distortion by luminance and radiological fields.

As an example in figure 2, it is shown the results of the resolution test analysis by SoftRACON software. In this test the programme searches the maximum and minimum grey levels in order to apply a threshold related to the lines pair per millimetre (lp/mm) detected resolution.

Figure 2: Resolution test results by SoftRACON software

The minimum and maximum grey levels represent the grey level for each pixel of the averaged profile. The resolution test is used to analyse the spatial resolution with different lines pair groups varying from 0.5 lines pair per millimetre (lp/mm) to 10 lp/mm. The reason of these maximum and minimum values is the intermediate spaces between the lines pair and depends on the dynamic gray range in the image. This type of profile is typical in images obtained by digital radiographic equipment.

II.C Image Quality Report and Database Storage

The information obtained by SoftRACON software from each zone of the phantom image is used to score this phantom image. Some of the parameters can be used to evaluate the image quality defining image quality indexes [6].

The results of the automated evaluation of a phantom exposure are organized in a report which is available to the radiographer. In this report some of the parameters are related to geometrical verifications. These parameters are:

- X-ray beam orthogonality.
- Radiation and light field alignment.
- Radiation field concordance with image support.
- Light field concordance with image support.

Other parameters are used to measure the detection of different tests that are embedded in the phantom:

- High resolution limit(lp/mm),
- Low contrast detectability by the Image Quality Figure (IQF) based on contrast and minimum resolution of the analysed image, that it is defined as follows:

$$IQF = \frac{1}{\sum_{i=1}^{n^{o}cols} C_i \cdot D_i} \cdot 100 \qquad (cm^{-2}) \tag{1}$$

where C_i is the thickness (contrast) associated with each column i and D_i is the minimum diameter (detail) of the detected objects in the column i. Higher IQF means higher image quality.

The phantom images obtained from radiographic equipment and the corresponding reports of results are kept in a database in order to compare results obtained on different dates. The graphical interface of the SoftRACON software is user-friendly and provides wide information about the functioning of image chain comparing with a reference image of the equipment.

III. RESULTS

In order to evaluate the performance of the presented facility, a large number of RACON phantom exposures obtained from several radiographic units have been analyzed by means of the SoftRACON package. These automated scores obtained by SoftRACON package have been compared with professional human observer's scores belonging to clinical institutions and independent of the SoftRACON developers.

Two digital radiographic image systems with different technologies have been considered:

1) Agfa CR 75: Computerized or indirect, digital radiography system (phosphor plate)
2) SIEMENS DR: Direct digital radiography equipment (charge-coupled device sensor).

The images have been acquired in DICOM format, which is nowadays the medical image extension implemented in digital radiographic equipment. DICOM files contain image data and metadata (in a header) that provide useful information about the image properties such as the image type, bits per pixel, resolution, display range…etc. For both radiographic systems, the image properties include 10 lp/mm resolution and 10 bits/pixel gray scale range.

We have obtained a sequence of five test exposures of the RACON phantom in each radiographic equipment. The working conditions were voltage: 50 kV, current: 25mA and time of exposure: 80ms. Out of this range of working conditions of the equipment, the images are over or sub-exposed and are not useful to evaluate their quality.

A total of ten digital radiographic images were considered and evaluated in two different ways: on the one hand, automatically by using the SoftRACON package and, on the other hand, visually by expert human observers belonging to other institutions. The scores in both cases have been compared to evaluate the efficiency and constancy of the analysis.

The reason to obtain five exposures in each of the imaging systems without change the working conditions of the equipment is to check the robustness of the SoftRACON software, i.e. the analysis must produce the same results for images obtained in the same working conditions of the equipment in a short time. The averaged results and standard deviation for the exposures on the two units of the considered radiographic equipments for geometrical and test analysis parameters, are given in tables I, II corresponding to radiographic equipment 1. Analogous results are given in tables III and IV corresponding to radiographic equipment 2.

In Tables I and III, the radiation and light field alignment, measured in cm, is the displacement between these two fields so theoretically this value is 0 cm when they are coincident. The radiation field-image support concordance and light field-image support concordance measured in cm, is 0 when they are of the same size and coincident.

Table I: Averaged scores of geometrical verifications for the exposures obtained from the Agfa CR75 equipment. Average value and standard deviation (in brackets) obtained for the five exposures.

Table II: Averaged scores of test analysis parameters for the exposures obtained from the Agfa CR75 equipment. Average value and standard deviation (in brackets) obtained for the five exposures.

Table III: Averaged scores of geometrical verifications for the exposures obtained from the Siemens DR equipment. Average value and standard deviation (in brackets) obtained for the five exposures.

Table IV: Averaged scores of test analysis parameters for the exposures obtained from the Siemens DR equipment. Average value and standard deviation (in brackets) obtained for the five exposures.

As it can be seen from the results in the tables, the SoftRACON results are consistent with human reader's ones. In addition, the deviation of the results by SoftRACON software is in general less than that of the human observers, because of the human subjectiveness criterion.

The standard deviation on experimental results by SoftRACON software is a bit high due to little variations of Kilovoltage, (Kv), current (mA) and time (ms) operating conditions of radiographic equipments.

IV. CONCLUSIONS

RACON test phantom and SoftRACON package developed permit an automated assessment of many image quality parameters which can be used to study the global state of the image system in an objective way.

The code allows comparing different images among themselves and with a reference image obtained with the software SoftRACON, that detects the test objects automatically, in determined functioning conditions of the equipment. In this sense, the application can be useful for the quality control of the equipment detecting its abnormal functioning. The deviation results prove the objectiveness obtained by the software, avoiding human variability. In addition, the SoftRACON and human observer results are quite similar due to the robustness of the software although it is sensible to little variations of operating conditions in the radiographic equipment

This software based on the aforementioned algorithms, is implemented in a graphical environment that makes it easier for the user to analyse the digital images obtained from quality control programmes of radiographic equipment.

V. REFERENCES

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Figures:

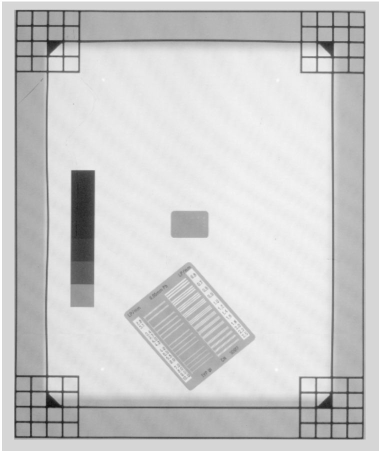

Figure 1: Radiographic image of RACON phantom

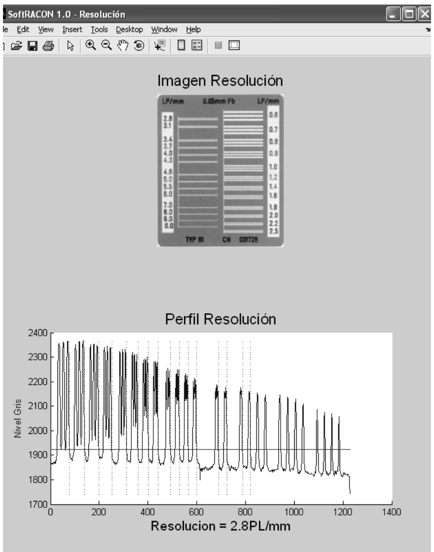

Figure 2: Resolution test results by SoftRACON software

Tables:

	X-ray beam orthogonality (º)	Radiation and light field alignment (cm)	Radiation field-Image support concordance (cm)	Light field-Image support concordance (cm)
SoftRACON	0.5 (0.2)	0.2 (0.1)	0.5 (0.1)	0.4 (0.1)
Human Observers	1 (1.2)	0.0 (0.0)	0.5 (0.2)	0.5 (0.2)

Table I: Averaged scores of geometrical verifications for the exposures obtained from the Agfa CR75 equipment. Average value and standard deviation (in brackets) obtained for the five exposures.

	Resolution (lp/mm)	Low contrast IQF (cm^{-2})
SoftRACON	6.8 (0.1)	65.4 (0.9)
Human Observers	6.2 (0.4)	60.5 (1.2)

Table II: Averaged scores of test analysis parameters for the exposures obtained from the Agfa CR75 equipment. Average value and standard deviation (in brackets) obtained for the five exposures.

	X-ray beam orthogonality (º)	Radiation and light field alignment (cm)	Radiation field-Image support concordance (cm)	Light field-Image support concordance (cm)
SoftRACON	0.8 (0.1)	0.5 (0.1)	0.6 (0.1)	0.5 (0.1)
Human Observers	1 (1.1)	0.1 (0.2)	1.0 (0.3)	0.5 (0.2)

Table III: Averaged scores of geometrical verifications for the exposures obtained from the Siemens DR equipment. Average value and standard deviation (in brackets) obtained for the five exposures.

	Resolution (lp/mm)	Low contrast IQF (cm^{-2})
SoftRACON	6.6 (0.11)	58.4 (0.8)
Human Observers	6.1 (0.46)	52.9 (1.4)

Table IV: Averaged scores of test analysis parameters for the exposures obtained from the Siemens DR equipment. Average value and standard deviation (in brackets) obtained for the five exposures.