**DE GRUYTER** Current Directions in Biomedical Engineering 2016; 2(1): 489–491

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# Numerical evaluation of image parameters of ETR-1

DOI 10.1515/cdbme-2016-0108

**Abstract:** In this work, we developed a method to handle the image quality test-tool precisely. This test-tool is important to evaluate the quality of the medical images for pre-treatment planning phase. But the achieved images are estimated by naked eyes, which does not provide the precise result. Our main goal is to get the desired image parameters numerically. This numerical estimation overcomes the limitation of naked eye observation. Hence, it enhances the pre-treatment planning. The ETR-1 test-tool is considered here. The contrast, the low contrast details and line-pairs (lp/mm) were estimated.

**Keywords:** Bresenham algorithm; ETR-1 image quality test tool; hough transformation; line-pairs.

## 1 Introduction

The recent researches on On-Board Imager (OBI) system show many approaches to analyze the image data. But the pre-treatment planning is highly dependable on the information of the image quality, which is generally checked by test tool. The research so far, does not show the numerical estimation of this test tool. This research was performed to bridge the gap of the field of medical imaging.

ETR-1 image quality test tool was considered into account. The contrast module estimates the contrast of the achieved image. The low contrast details are evaluated by some sort of small indicators. The high contrast line-pairs (lp/mm) are measured by two parallel indicators, mounted on the resolution module unit.

## 2 Material and methods

### 2.1 ETR-1 image quality test tool

ETR-1 is a multi-purpose test tool to evaluate the image quality of all types of radiographic and fluoroscopic systems using films. It is manufactured by Scanditronix Wellhöfer GmbH [1]. The test-plate merely consists of a contrast module and a resolution module. The resolution module is moreover, consists of a resolution measurement unit, the low contrast details and a measuring area of the optical density. There are some alignment marks and centering rings in different formats. A centimeter scale and a centering tube is also available in this test tool.

Exposure geometryis also useful for various types of investigations. Adjustment of image intensifier size, as well as, the alignment of the light field edges to the X-ray field are controlled by this parameter. Moreover, it is helpful for the alignment of light field center with the center of the image. Magnification (scale length of the test pattern vs. the actual scale length) is also maintained by the exposure geometry. Centering tube for checking the perpendicular beam is also available in the test tool ETR-1.

### 2.2 Canny algorithm

The canny algorithm works based on three criteria namely good detection, good localization and only one response to a single edge.

Assuming the finite impulse response of the filter is $f(x)$, bounded by [−w, +w]. The edge itself is referred by $G(x)$. The root mean square noise amplitude per unit length is $n_0$. Then the signal to noise ratio (SNR) criterion [2] is given by Eq. (1).

$$\mathrm{SNR} = \frac{\left|\int_{-w}^{+w} G(-x) f(x)\, dx\right|}{n_0 \sqrt{\int_{-w}^{+w} f^2(x)\, dx}} \tag{1}$$

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The higher SNR ensures that a real edge is not missed, while the non-edge point is not detected as the edge.

The localization accuracy criterion [2], is followed by Eq. (2).

$$\text{Localization} = \frac{\left| \int_{-w}^{+w} G'(-x) f'(x)\, dx \right|}{n_0 \sqrt{\int_{-w}^{+w} f'^2(x)\, dx}} \tag{2}$$

Finally, the one response criterion [2] is considered which minimizes multiple responses to a single edge. The mean distance between zero-crossing of $f'$ is $x_{zc}$. Then we write,

$$x_{zc}(f) = \pi \left[ \frac{\int_{-\infty}^{+\infty} f'^2(x)\, dx}{\int_{-\infty}^{+\infty} f''^2(x)\, dx} \right]^{1/2} \tag{3}$$

The Auto threshold was used to visualize the test-plate image. Canny edge detector and image dilation allows to observe the geometric shapes of the plate properly, especially the central ring of ETR-1. The entire canny algorithm works based on these three criteria given by Eq. (1–3).

## 2.3 Circle Hough transform

In a two dimensional space, a circle can be represented as $(x-a)^2 + (y-b)^2 = r^2$, where, $(a, b)$ is the center of the circle in cartesian coordinate and $r$ is the radius. Thus, the parameter space would be $(a, b, r)$, i.e. three dimensional. Circle detection process can be divided into two stages. The first stage is finding the optimal center of circles in a 2D parameter space. The second stage is to find the optimal radius in a one dimensional parameter space [3].

Once we have the detected edge of cental ring by canny edge detection, the central ring of ETR-1 image quality test tool was detected by circle Hough transform. The center was then extracted for further processing.

## 2.4 Bresenham line algorithm

Assuming, $\Delta x = x_2 - x_1$ and $\Delta y = y_2 - y_1$. Bresenham algorithm begins with a starting point and then it increments the x-coordinate by one. It is not interested to track the y-coordinate (which increases by the $m = \Delta y/\Delta x$, each time the x increases by one). At the same time, it keeps an error bound $\epsilon$ at each stage, which represents the negative of the distance from the point where the line exits the pixel to the top edge of the pixel. The value of $\epsilon$ is first set to $m - 1$, and is incremented by $m$ each time the x-coordinate is incremented by one. If $\epsilon$ becomes greater than zero, it means that the line has moved one pixel upwards. For this reason, we must increment the y-coordinate and adjust the error to represent the distance from the top of the new pixel. It is done by subtracting one from $\epsilon$ [4].

We used this algorithm both for the treatment of the contrast module, as well as, the resolution module to estimate the high contrast line-pairs. The intensity curve of the contrast module is found from the bresenham lines. In resolution module unit, two sets of bresenham lines were created to evaluate the lp/mm.

## 2.5 Tracking the test-plate

Two binary masks were created to get a mask difference. This mask difference as a circle touches the lower corners of the contrast module. The dynamic location of the test-plate was determined mathematically to track the test-plate. This tracking is useful for the unexpected orientation of the test-plate. The highest intensity point of the entire image was chosen as reference. With help of this point and the test-plate center, another lower corner of contrast module was calculated.

## 2.6 Extracting the image parameters

We evaluated three types of image parameters by our developed program. The contrast $(C)$ of the contrast module was calculated from the intensity curve which was found by applying the bresenham line algorithm. Finally, the contrast was calculated by Eq. (4).

$$C = (L_{max} - L_{min})/(L_{max} + L_{min}) \tag{4}$$

The notation $L_{max}$ and $L_{min}$ denotes the maximum and minumum brightness of the most neighbouring units of the contrast module.

The low contrast details were handled by creating five binary masks. Rectangular grids in 2-D space were created for this purpose. A reference contrast unit onto the optical density measurement area was considered to compare the contrast details graphically.

For high resolution line-pairs, the conventional way of finding the lp/mm was followed. Bresenham algorithm permits fix it onto the resolution module unit. Both line-pairs columns were considered. The important image parameters were extracted as numerical figures and showed in a graphical manner.

## 3 Results and discussion

For a specific test image, we found the parameters contrast, low contrast details and high contrast line-pairs (lp/mm). We also measured the intensity level difference and the contrast lengths for the contrast module. For all cases, the Matlab program returns the numerical figures as matrices and the graphical illustrations.

Matlab program returns the contrast row vector as below,

Contrast = 0.13 0.19 0.25 0.35 0.51 1.00

The intensity difference (ID) is found as,

ID = 79.64 118.34 155.16 220.05 318.60 615.66

We got the contrast length (LC) as row vector as following,

LC = 40.00 46.00 43.00 44.00 45.00 41.00 36.00

The low contrast indoicators (LCI) were achieved as,

LCI = 1.0000 0.9994 0.9987 0.9979 0.9997

The normalized contrasts of the contrast module for six units are observed from Figure 1. The low contrast details are shown in Figure 2.

## 4 Summary

The smoothness of the resolution curves depend on the material of the resolution module. The extended bresenham lines in both sides allows to achieve the gradually starting curves. More bresenham lines make sure the accuracy of the resolution curves. That is why, we tried to maintain the width of line-pairs columns as large as we can.

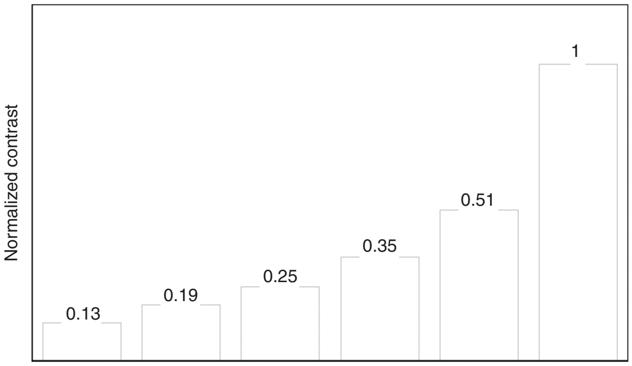

**Figure 1:** Normalized contrast for the contrast module. In case ideal orientation, contrast was measured from left to right units of the contrast module.

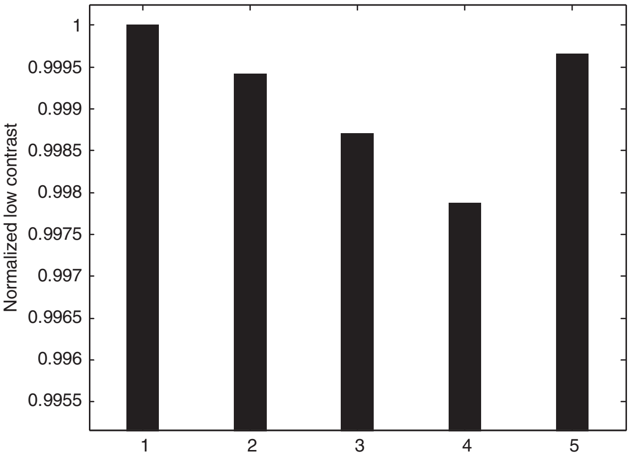

**Figure 2:** Found low contrast details. The right most bar is the reference contrast. The nearest unit to the reference, has the minimum contrast.

The numerical figures and the graphical illustrations of the image parameters imply the correctness of the whole process. The contrast of the contrast module returns the six different contrast units. The low contrast details, for four small indicators are also determined. The resolution module was handled by estimating the line-pairs and the modulation transfer function. The process was proved to applicable for both the ideal images, as well as, for the noisy images.

**Acknowledgment:** The authors thank to Radiotherapy department of Ostprignitz-Ruppiner Gesundheitsdienste GmbH (Brandenburg, Germany) for providing the necessary equipments.

### Author's Statement

Research funding: The author state no funding involved. Conflict of interest: Authors state no conflict of interest. Material and Methods: Informed consent: Informed consent is not applicable. Ethical approval: The conducted research is not related to either human or animal use.

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