Abstract: - A set of images of a commercial quality control phantom are presented to the students. They were acquired using a Computed Tomography scanner, following an internationally established quality control protocol. After the completion of the exercise all students should be able to manipulate the images in order to define the values of several parameters affecting image quality. The resulting benefit for the student is the ability to perform quality control procedures for significant functional parameters on a Computed Tomography scanner.

Key – Words: - Computer Assisted Exercise, Quality Control, Computed Tomography

1 Introduction

The increased availability and power of modern computers has made them an appealing teaching tool. Multimedia-aided applications can simulate a large number of real-life devices or situations. Medical imaging modalities, such as Computed Tomography (CT) are no exception. A CT scanner is regarded as complex medical equipment [1,2]. In order for the image produced to be a reliable source of diagnostic information, quality control (QC) procedures have to take place in regular time intervals to verify its performance. The purpose of this laboratory exercise procedure is to provide the outcome of a quality control program of a CT scanner, giving the ability to students to interact with the resulting images and measurements. Moreover, the students are asked to produce a QC report based on the given data.

2 Methodology

2.1 Test object

The parameters are based on the Performance Phantom-C (figure 1) and the procedures employed throughout the laboratory exercise are proposed by Philips Medical Systems [5,6] for the Quality control of its Tomoscan AVPS and Tomoscan AVEP systems.

Fig. 1. Performance Phantom-C [5]

2.2 Software

There are several software packages freely available on the Internet and the students are encouraged to use them in their own time. The laboratory uses DicomWorks 1.3.5
2.3 Parameters
Several parameters are used to depict the performance of a CT scanner. The parameters chosen for the purposes of this laboratory exercise are:

2.3.1 High Contrast Resolution
The section of the phantom (Figure 2) contains nine discrete areas. Each one of these consists of four thin aluminum plates with thickness 1.0, 0.75, 0.7, 0.65, 0.6, 0.55, 0.45, 0.4 and 0.35 mm respectively, separated by thin polyester plates of the same width. Aluminum is used because it has high specific absorbance to X-rays compared with water, which fills the surrounding area of the phantom. The high contrast resolution of any image is reported as the highest spatial frequency that can be displayed. In CT, using this specific phantom, the aluminum plates mentioned above are depicted as lines. The area where the lines present the highest spatial frequency and can still be discriminated using proper window settings is the high contrast resolution [4,5].

High contrast resolution varies with dose. The anatomical region to be examined and the kind of examination to be performed require different levels of resolution [2]. In order to keep dose low and at the same time have adequate information, a variety of scanning parameters are available for any CT scanner. In order to accurately describe the resolution of the scanner, one must perform the test for every exam. For practical reasons, two measurements are performed. The first one is for “Normal imaging” (lowest resolution, used in the imaging of large organs such as the liver or spleen) and the second one for “High resolution imaging” (highest resolution, used in imaging small organs such as the inner ear) [4,5].

![Fig.2. Slice which zoomed slice for the high contrast resolution test](image)

2.3.2 Low Contrast Resolution
It is important to visualize lesions with content similar to the surrounding tissue. Low contrast resolution represents the ability of the physician to distinguish areas of similar, yet not with the same absorbance to X-rays [1,2,7]. The section of the phantom used for this parameter (Fig 3) contains three circular disks 0.075, 0.4 and 1.6 mm thick with nominal contrast level 0.22%, 0.5% and 1.8%. Each disk contains eight holes of 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 mm diameter which represent the different contrast levels. The low contrast resolution is calculated by multiplying the actual level of the CT number of one of the disks with the diameter of the smallest visible hole of the same disk.

![Fig.3. Low contrast resolution measurement](image)

2.3.3 Uniformity
The CT scanner is able to discriminate a large number of absorbance levels; much larger than the human eye can. A number often stated as “CT
number” or “Hounsfield number”, ranging from –1000 to 1000 and it is used to describe the attenuation of each pixel of the image (Equation 1). A homogenous area should have the same CT number. Uniformity is the parameter that verifies that the same material is presented the same way in all parts of the slice.

\[ CT \text{ number} = \frac{\mu_{\text{tissue}} - \mu_{\text{water}}}{\mu_{\text{water}}} \times 1000 \]  

[1]

where:

\( \mu \): Linear attenuation coefficient

This section is filled with distilled water, in order to produce a homogeneous object from which the CT number is measured in several areas. Regions of Interest (ROIs) are defined at the center of the slice and four similar ROIs symmetrically near the edge of the slice. The average CT number of each ROI is compared to the others and the theoretical value (zero) (Figure 4).

**2.3.4 Image noise**

Noise is a way to describe the accuracy of the reported CT numbers. At the same ROIs where uniformity was measured, standard deviation (\( \sigma \)) is calculated from Equation 2.

\[ \sigma = \sqrt{\frac{\sum (CT_i - CT)^2}{N-1}} \]  

[2]

where

\( CT_i \) is the number of each pixel, \( CT \): mean value of the ROI and \( N \): Number of pixels in the ROI.

**2.3.5 Slice Thickness**

The part of the section used is consisted of two crossed aluminum ramps of 0.6 mm width. The angle between them is 53.13° degrees and it’s bisect is parallel to the axis of the scan. Each ramp is displayed as a rectangle on the slice plane. The Full Width at Half Maximum (FWHM) of the curve of the CT numbers across the ramp is the slice width. One way to measure FWHM is to find the maximum CT number in the ramp projection is found and subtract the value of the surrounding medium. Window level is set at half of the resulting value and the width of the ramp projection is measured with window width at minimum (Figure 5).

**2.3.6 CT Number Linearity**

CT number characterizes the tissue. The ability of the scanner to correctly relate CT number to materials is measured by the phantom area shown in Figure 6. Four different materials in cylindrical shape are projected as four circular areas. Each one consists of a different material (Teflon, Acrylic Resign, Polyethylene and Air into Acrylic). CT number is measured for each and is compared to given nominal values.
2.3.7 Line Spread Function (LSF)
LSF is an approximation response of the system to a Dirac function. The section contains one stainless steel wire of 0.18 mm diameter. The measured value is again the full width at half maximum. Two measurements are made, the first for “Normal imaging” and the second for “High resolution imaging”.

2.3.8 Coincidence of Visual Targeting System with Slice
For this parameter, a ring of metal wire or metal wire markers is placed along the perimeter of the phantom. The ring is positioned as accurately as possible at the slice position shown by the targeting system. The complete ring or all the metal markers should be visible. For the slice shown in Fig. 7 a metal marker was placed on the top of the phantom.

2.4. Given data
Students are given the results of a real-life Quality Control procedure, i.e. the images of a QC phantom in DICOM-PACS format. Slices containing the above details are available. The student must choose the proper slices and perform the evaluation of the parameters described above.

3 Conclusion
The procedure described above is a significant part of QC procedure of a CT scanner. The outcome of the exercise would be an evaluation of the given set of images (and the corresponding scanner). The student must choose the proper slice, area and window settings as well as the proper software tools to achieve optimum results. At the completion of the exercise the students not only will have gained a full overview regarding QC of a CT system but they will be able to manipulate with great expertise a CT image.

In the future the exercise could be enhanced by introducing errors, e.g. in positioning of the phantom or the reconstruction technique to demonstrate the problematic as well as the “normal” images. Different phantoms for the same parameters could be used to trigger student creativity. All the above require only a regular computer laboratory and access to scanner(s) able to produce digital output on convenient media, such as a recordable CD.

4 References
[3] New Jersey Department of Environmental Protection: Compliance Guidance for Computed Tomography Quality Control, 01/11/01