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DEVELOPMENT AND CHARACTERISATION OF A RADIATION SCANNING SYSTEM FOR SMALL ORGAN STUDIES

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ABSTRACT

Preliminary results obtained with a prototype of a radiation imaging device to be used in a system for automatic processing of thyroid images in medical pre-diagnostic are presented. The detector and the collimator were projected to work with ^{131}I and ^{99m}Tc radioisotopes. The characteristics of the scanning system were analysed using a set of different phantoms to determine its spatial resolution. The obtained results are comparable to other medical equipments usually applied for diagnosis.

Key words: automatic processing of images, thyroid images, medical pre-diagnostic.

RESUMO

São apresentados os resultados preliminares obtidos com o protótipo de um sistema de obtenção de imagem por radiação para processamento automático de imagens da tireóide em pré diagnóstico médico. O detector e o colimador foram projetados para trabalhar com os radioisótopos ^{131}I e ^{99m}Tc. As características do sistema de varredura foram analisadas usando uma série de diferentes simuladores para determinar a sua resolução espacial. Os resultados obtidos são comparáveis aos de outros equipamentos médicos usualmente empregados para diagnóstico

Descritores: processamento automático de imagem, imagem da tireóide, pré diagnóstico médico

INTRODUCTION

According to data from the Brazilian Society of Biology and Nuclear Medicine there are in Brazil about 150 laboratories offering services in the Nuclear Medicine area and 40% of them using linear scanner devices. This service is applied to a few tens of thousand of people per month, in average all over the country. There are about 73 types of clinical tests commonly indicated by Brazilian physicians in this category, and about 30% of them correspond to evaluation of the thyroidal function. The utilisation of a linear scanning device is justified by lower operational cost and less time necessary to obtain images from small organs (like thyroid), when compared to a gamma camera.

Recent works in this area [1,2] indicate that the use of artificial intelligence techniques, specifically artificial neural networks, for processing medical images is a promising method, that allows automatically to obtain reliable results with a faster processing, when compared to the conventional processing methods. More over, to optimise scanner components, i.e., detection system, collimator, scanning system, digital image processing, device control and operation software, is an important factor to perform diagnostics with quality.

In a typical thyroidal study a proper radiopharmaceutical, which is accumulated in the thyroid [3,4] is administered to the patient in order to obtain the image of the obtained radioisotope distribution. The scintillographic image obtained from such study allows evaluating the organ's state, locating the exact position for surgery, etc. A scintillographic image from a small organ as thyroid, allows to determine the gland's position, either normal or abnormal (ectopic gland). The gland's relative size might indicate diseases such as hyperthyroidism. It is also important to search for nodes: hot nodes, with activity higher than the normal cells and cool nodes, with less activity. In a few cases has been observed nodes with the same activity of the normal tissue [5].

In this work it is discussed the materials and methods used to develop and characterise a prototype of scintillographic scanner device to be used in thyroid and other small organs studies and the obtained results. The scintillographic scanner is part of a system that is being developed at IPEN for evaluation of the thyroidal function with automatic analysis using artificial neural networks. The detector system utilises a scanning control to map the region under study and to create the image of the radiation-emitting organ projected on the scanning plane. The modulation transfer function of the device was evaluated by two methods: the statistical moments method and by direct measurement of the Fourier's transform.

Materials and Methods

The scintillographic scanner consists of two main parts: the radiation detection system and the control and acquisition module.

Radiation Detection System

The radiation detection system is composed by a NaI(Tl) scintillator detector (∅76mm x 25mm) and a lead collimator that is located at the intersection point of the scanner axes, controlled by a couple of step motors. The detection system presents an energy resolution of 12% for ^{99m}Tc (E_γ=140,51keV) photo-peak.

The lead collimator was designed to work with ^{131}I and ^{99m}Tc, the 1cm thick walls attenuate the most energetic radiation of ^{131}I (E_γ=364.48keV) as much as 10 times. The cylindrical channel with 1mm diameter allows collimating the radiation with a good spatial resolution.

Control and Acquisition Modules

A SYNCRO ICH_XY controller and a NOVELEC SM512 multichannel analyser form the control and acquisition modules.

The NOVELEC SM512 is a portable multichannel analyser with an RS-232 serial link connected to a microcomputer with all its functions available in a fully programmable interface. It was configured to work with the gamma radiation of ^{99m}Tc.

The ICH_XY module is also linked to a microcomputer via RS-232 and its programmable logic allows to operate the scanner and to keep control over the detection system's position and state.

A set of MS Visual Basic modules was developed to control and monitor both SM512 and ICH_XY via standard serial ports.

All modules were integrated in single software that allows monitoring all the required parameters during the process of scanning, until each image is obtained. This software takes into account some adjustments needed during data acquisition, such as compensation for radioisotope decay during the acquisition period. A series of norms were observed to guarantee the software development process with reduced errors and according to specifications, as described by Rosen [6].

Scanner Performance in Image Acquisition

The capabilities and performance of the scanning system to obtain images of the radiation distribution were tested using a set of simulators with different geometries. In all cases a safe amount of ^{99m}Tc was used to create the active region. Figure 1 shows the image obtained using a point source with ∅=2mm.

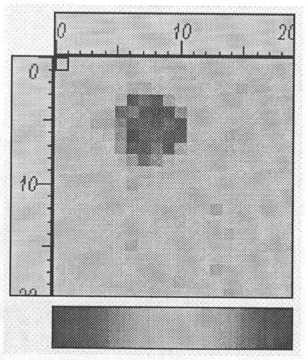


Figure 1: Image obtained from a point source of ^{99m}Tc with ∅ = 2mm.

A set of thyroid simulators obtained with several pieces of filter paper saturated with ^{99m}Tc solution was also used. One of the obtained images is presented in Figure 2.

Murphy [7] presented a wide discussion of the relevant characteristics in evaluating a scanner device from the point of view of plane image acquisition. The most important parameter for this work is the scanner's spatial resolution, i.e., the device capacity to detect two objects situated one close to the other as two different entities. An indicator of the spatial resolution is the full width at half-maximum (FWHM) that gives the point spread function (PSF) or the line spread function (LSF). While the LSF provides a complete description of the resolution, it is not in a very convenient form. A most convenient way is to use the Modulation Transfer Function (MTF).

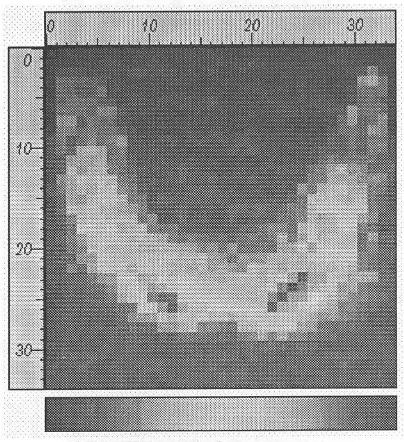


Figure 2: Image obtained from a thyroid simulator.

Determination of the Modulation Transfer Function.

The Modulation Transfer Function (MTF) offers the most complete characterisation of the spatial resolution of a scanning device, assuming that the system response is linear. While the condition of linearity isn't hold in this case, MTF is a good approximation and is very useful in evaluating the spatial resolution. The MTF is the spectrum of spatial frequencies that the device is able to reproduce [7,8,9] and measures the contrast transfer from the object to the image as a function of the spatial frequency (object dimension).

The difficulty in comparing the performance of different types of devices has long proved a challenge. There have been devised a set of methods to objectively measure the spatial resolution of imaging devices [10,11,12]. All of them require a careful measurement of the LSF in order to calculate the FWHM and them the MTF [7]. For example, the NEMA standard [6] to evaluate the spatial resolution using the LSF requires acquiring a digital image using a linear source 1mm wide.

Meanwhile, other methods have been proposed to simplify this task with a cost in terms of loss of precision, but with the advantages of being quick and using simple equipment. One of these methods is based on computing the statistical moments in images of bar simulators with different step width [13]. Using the statistical moment method it can be computed an approximation to the actual MTF:

$$MTF(f) = \frac{[Peak(f) - Valley(f)]/2}{[Peak(f) + Valley(f)]/2}$$

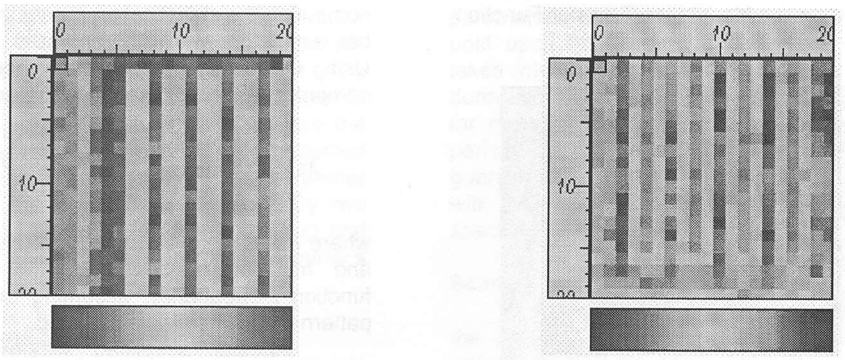
where *Peak(f)* and *Valley(f)* are the maximum and minimum values from the sinusoidal function *f* frequency, assuming that the bar pattern in the image is a sinusoid.

Another simplified version for this method is that proposed by Fujita [14] with the modification of the method proposed by Yu et al. [15]. This method uses the image obtained from a uniform simulator with linear edge in the scanner's vision field. This edge must be oriented parallel to either the columns or the rows in the image. An approximated image of a thin linear source is obtained numerically differentiating the edge image, obtaining a LSF(x). The Fourier transform is applied to the LSF(x), to obtain the optic transformation function OTF(*f*). The MTF(*f*) is obtained as the modulus of the OTF(*f*).

Both methods are in some way approximated, however, applying both in connection it is possible to evaluate more precisely from the point of view of image acquisition, with sufficient accuracy and low costs in terms of time and equipment. Simulators with banner form with different widths where constructed to apply the method of statistical moments. The simulators were made with filter paper saturated with a ^{99m}Tc solution. Afterwards the piece of paper with the radioisotope incorporated was sealed with several layers of plastic to allow the use without any risk of contamination. Simulators with bars of different widths: 1,5mm, 2mm, 3mm and 4mm were prepared and measured. All radiological protection security requirements were observed. The images obtained are presented in Figure 3 (A, B, C and D) respectively.

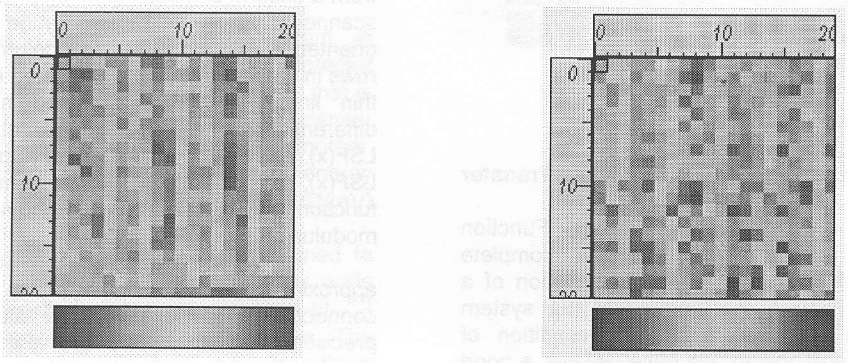
The measurement time for each point was 10s. The use of a collimator with a thin channel guarantees a good spatial resolution (the bar simulator with d=1,5mm is reproduced adequately in Figure 3A) at a cost of efficiency loss. This problem should be addressed with the development of a multichannel focal collimator.

To compute directly the MTF(*f*) it was obtained the image of an extended simulator with an edge in the centre of the scanner's vision field. All measurement conditions were the same. The image obtained is presented in Figure 4.



A: Image of bar simulator d = 1,5mm.

B: Image of bar simulator d = 2mm.



C: Image of bar simulator d = 3mm.

D: Image of bar simulator d = 4mm.

Figure 3: Images of bar simulators of **A** : d = 1,5mm, **B** : d = 2mm, **C** : d = 3mm and **D:** d = 4mm.

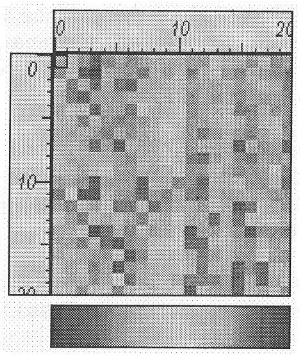


Figure 4: Image of an edge simulator.

The Fourier transform FT (zero padded to use a fast FT algorithm (Press et al.,1993) [16] was applied to the LSF(x) obtained from the image's numerical derivative. The Module of OTF(*f*) gives directly the MTF(*f*). The MTF(*f*) calculated in such a way presents high values for frequencies above 0,45mm^{-1}. This is the result of the effect of aliasing in calculating the FT, due to the sampling with finite intervals (step Δ=1mm) of noisy data. In fact, the random noise of nuclear data is treated as components of frequency above the critic frequency of Nyquist $f_c=1/(2\Delta)$, and the power corresponding to this interval of frequencies is transferred to the extremes of the definition interval $[-f_c, f_c]$ of the FT [16].

Results

The maximum error obtained in the detector position of the scanning system was 0,12mm.

Figure 5 presents the resulting MTF(*f*) obtained using both methods. The points obtained with the statistical moments methods are in good agreement with values from MTF(*f*) (note that the continuous curve is a representation of an ideal MTF(*f*), for illustration purposes).

These values for spatial resolution are comparable to those of gamma camera [13]. The results of characterisation of the scanning device presented in Figures 3 and 4 and in the graphic MTF(*f*) in Figure 5 allows to discriminate details of the order of 1,5mm. It means that the obtained images are adequate to the task of obtaining images of small organs such as thyroid.

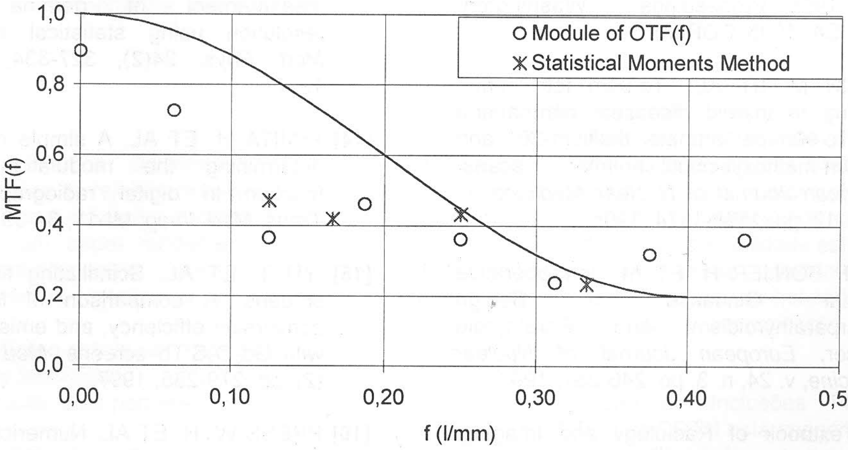


Figure 5. MTF(*f*) calculated with both Statistical Moments and Fourier Transform of LSF(x).

Conclusions

The prototype system was found adequate to obtain images from small organs, but it presents a limited efficiency due to its good spatial resolution. In the next stage of this work, it will be used a multichannel collimator that will enhance the detection efficiency without degrading the spatial resolution. Despite its use in thyroid imaging tests, the developed system could be used as well for studying other small human organs and small animals, like those used in molecular biology research.

Acknowledgements

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REPOSITÓRIOS
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Um estudo d
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INTRODUÇÃO

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3) Estudos petrológi
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