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# PHOTON SPECTROMETRY UTILIZING NEURAL NETWORKS

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## ABSTRACT

Having in mind the time spent on the uneventful work of characterization of the radiation beams used in a ionizing radiation metrology laboratory, the Metrology Service of the Centro Regional de Ciências Nucleares do Nordeste - CRCN-NE verified the applicability of artificial intelligence (artificial neural networks) to perform the spectrometry in photon fields. For this, was developed a multilayer neural network, as an application for the classification of patterns in energy, associated with a thermoluminescent dosimetric system (TLD-700 and TLD-600).
A set of dosimeters was initially exposed to various well known medium energies, between 40 keV and 1.2 MeV, coinciding with the beams determined by ISO4037 standard, for the dose of 10 mSv in the quantity Hp(10), on a chest phantom (ISO slab phantom) with the purpose of generating a set of training data for the neural network. Subsequently, a new set of dosimeters irradiated in unknown energies was presented to the network with the purpose to test the method.
The methodology used in this work was suitable for application in the classification of energy beams, having obtained 100% of the classification performed.

## 1. INTRODUCTION

The high quality of a ionizing radiation metrology laboratory is closely connected to the correct characterization of radiation beams used in their services. Periodically, these beams are checked to ensure that there is always the certainty of continued compliance with established standards, and the suitability of the work performed.

In order to minimize the time spent and increase the optimize of the characterization of radiation beams used in this kind of laboratory, the Metrology Service launched this work in order to use a mechanism that would be able to recognize, such as a simple look, the beam to which a dosimeter was submitted. For this, we used a system composed of a neural network, which is the computational code that most closely approximates the operation of the human brain to perform the recognition of energy beams used in laboratory routine by their behavioral characteristics from the reading of thermoluminescent dosimetric cards with lithium fluoride, which, used widely in services of individual monitoring, have well established response and can be reused several times. This feature is especially attractive because it provides low cost procedure and the CRCN-NE already has a Laboratory of Individual Monitoring with all the necessary infrastructure.

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## 2. METODOLOGY

The implementation of this work aimed at the recognition of mean energies of the radiation beams to which the dosimeters are subjected is composed of two major steps: one that could be called project infrastructure, composed by obtaining the input data, creation of the neural network and training of the network; and another step that consists of the test of the network in a actual use situation, where are presented dosimeters irradiated to the recognition of mean energy (or ISO quality) used to irradiate the dosimeters.

### 2.1. Project Infrastructure

With the objective to provide an application for use in the test phase, it was necessary to generate a mass of input data for the neural network that could characterize well the beams used in the laboratory. At this point, it was necessary to implement a pre-processing to highlight the differences between the results of the dose equivalent ($H_p(10)$) obtained with thermoluminescent dosimeters. After this treatment, the data were entered in the neural network in order to perform a training taking as basis the mass of data obtained and a "template" of responses that should be provided.

#### 2.1.1. Obtainment of input data

To obtain the input data was used the dosimetric system manufactured by Thermo Electron Corporation, same manufacturer of thermoluminescent readers employed in this work, Harshaw 6600, which consists of a plastic badge with different filters in which is inserted a dosimetric card composed of four thermoluminescent crystals (TLDs) encapsulated between two sheets of teflon (PTFE) thick 10 mg/cm$^2$ mounted on a aluminized card identified by barcode. The crystals used were TLD700 ($^7$LiF: Mg, Ti) and TLD600 ( $^6$LiF: Mg, Ti).

Above each of the TLDs there is a filter set in the badge that allows to discriminate the types of radiation and particles (α, β, γ and neutrons), so that the combination between the type of dosimeter and the filter permits to extract different information as dose equivalent in depth, dose equivalent to the lens of the eye, etc. In this work was used the following configuration of dosimeters and filters in accordance with the position of the dosimetric card: Position 1: Filter of ABS plastic (242 mg/cm$^2$)+copper (91 mg/cm$^2$) on a TLD 700. Position 2: Filter of ABS plastic (107 mg/cm$^2$)+ PTFE (893 mg/cm$^2$) on a TLD 700. Position 3: Filter of PTFE+aluminized Mylar (a total of 17 mg/cm$^2$) on a TLD 700. Position 4: Filter of ABS plastic (300 mg/cm$^2$) on a TLD 600.

The irradiations for the generation of training data were performed in groups of 4 dosimeters at a time, placed on the ISO slab phantom (30 x 30 x 15 cm$^3$), composed of PMMA (poly methyl methacrylate) and filled with water, as shown in figure 1, at a distance of 3.4 m from the X-ray tube or 1.0 m from the source of $^{137}$Cs or $^{60}$Co and with a dose equivalent of 10 mSv,).

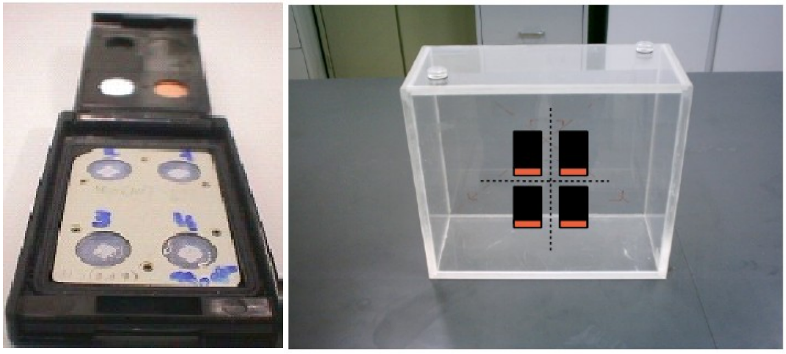

**Figure 1. Open badge and the slab phantom with the dosimeters positioned for irradiation.**

The beams used for the generation of the input data were the ISO radioprotection qualities N40, N60, N80, N100, N150, N200, obtained from an industrial X-ray PANTAK 320 kV, and the sources of $^{137}Cs$ and $^{60}Co$, corresponding to mean energies of 33, 48, 65, 83, 118, 164, 662 and 1250 keV respectively.

### 2.1.2. Pre-processing of data

From the assays performed with the dosimeters in the chosen beams, it was proved to be necessary to carry out a pre-processing on the files delivered by reader. In order to highlight the differences between the data delivered, was created a small application to integrate the readings of 200 channels of each TLD, giving a value of the area under the luminescence curve of each crystal, saved in the format of a file containing the number of dosimetric card and the result of the four integrations.

### 2.1.3. Creation and training of the neural network

To perform the classification of the energy beams, it was opted for an neural network type back-propagation having several output neurons, one for each possibility of classification (BG, N40, N60, etc.), scored in the range of values between 0 and 1, which is the interval of a sigmoid function, used in the neurons, according to the probability that the dosimeter has been irradiated to that energy (or not, in the case of BG).

The numeric value taken as the response of the network was the major value provided by set of output neurons for a given dosimeter, and can extrapolate the indicated range for the desired output (between 0 and 1) according to the calculation obtained at the end of the processing of many neurons of the neural network.

For the implementation and training of the network was used Matlab® software, having been writing a specific code for this purpose. After several tests changing the topology of the network and the number of iterations, a schema was defined with a four neurons input layer, two hidden layers and an output layer with nine neurons, which were the possibilities of beams to be recognized and the BG. Figure 2 shows the schema used for the implementation of the neural network.

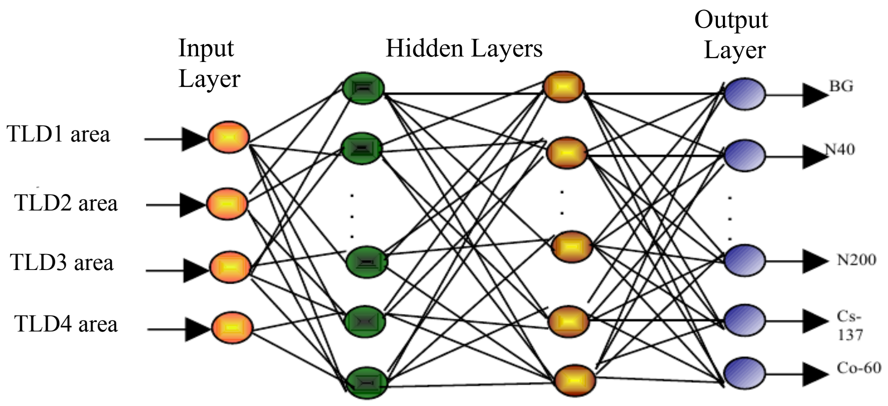


**Figure 2. Neural Network schema**

To carry out the training, the network has received as input files containing the number of the dosimeter, the four areas of the thermoluminescent dosimeters reading and the correct response to that identification, which was a response value that should be presented in the output of the network at the end of the processing, so that the network can balance their weights in order to achieve the desired output. This procedure was performed with multiple dosimeters irradiated in the various radiation beams. Obtaining satisfactory response in training, remained to the network the test in a actual usage situation.

## 2.2. Test of the neural network

To check the response of the application tool developed in actual usage situation, several irradiations were performed with the same beams used in training of the neural network and the input files were introduced into the network without the output response. For the beam components of the training, the recognition achieved 100% accuracy. This way, it was concluded that the network has reached its best setting. Figure 3 shows the format of the response of the neural network.

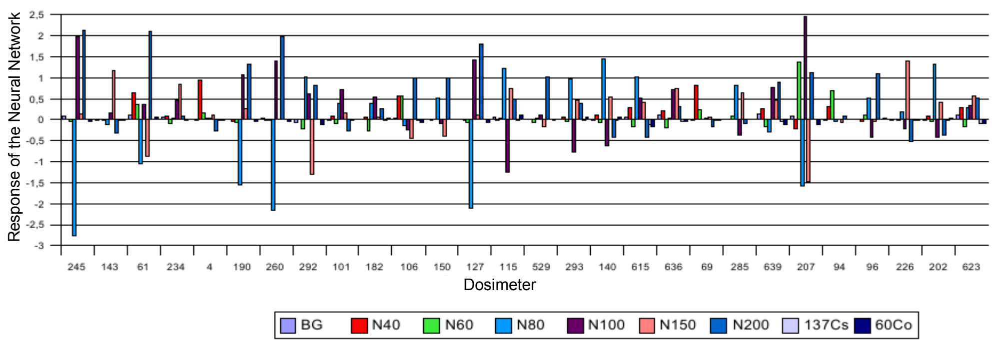


**Figure 3. Response of the neural network**

## 3. CONCLUSIONS

The network developed for the recognition of energy in photon fields has proven to be appropriate for the implementation of the recognition of energies for irradiations in $H_p(10)$ with a dose of 10.0 mSv, having performed correctly the identification in 100% of cases. However, it is required the input data to be appropriately processed to enhance the characteristics that enable differentiate correctly each energy standard and the number of iterations of the neural network training to be well defined in such a way that it does not lead to addiction of the network or the failure of the recognition of patterns.

Subsequently must be implemented the same procedures for the verification of the response of the neural network for a wider range of doses, specially the lowest, where there may be noise interference among other factors.

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