# Development of a new software tool, based on ANN technology, in neutron spectrometry and dosimetry research.

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***Abstract***

Artificial Intelligence is a branch of study which enhances the capability of computers by giving them human-like intelligence. The brain architecture has been extensively studied and attempts have been made to emulate it as in the Artificial Neural Network technology. A large variety of neural network architectures have been developed and they have gained wide-spread popularity over the last few decades. Their application is considered as a substitute for many classical techniques that have been used for many years, as in the case of neutron spectrometry and dosimetry research areas. In previous works, a new approach called Robust Design of Artificial Neural network was applied to build an ANN topology capable to solve the neutron spectrometry and dosimetry problems within the Matlab® programming environment. In this work, the knowledge stored at Matlab® ANN's synaptic weights was extracted in order to develop for first time a customized software application based on ANN technology, which is proposed to be used in the neutron spectrometry and simultaneous dosimetry fields.

**Keywords:** Neutron spectrometry and dosimetry, ANN, RDANN

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## Introduction

Spectrometry measurements and dose calculus have played a vital role in helping to understand the nature and origins of ionizing radiation [1]. As mentioned by Vega-Carrillo et al in 2007 [2], the measurements and calculations of neutron fluence spectra are a key factor in radiation protection dosimetry of neutrons, mainly because there are different neutron sources that can impact the working conditions [3]. Although there is a wide range of different devices used for neutron spectrometry, the majority of the instruments can be grouped together into a small number of broad categories, each one based on a common underlying technique [4]. These categories are time-off-flight, nuclear reaction methods, nuclear recoil methods and the use of integral detectors. In the integral detectors, neutron dosimeters are utilized as multi-element systems, as in the case of the Bonner Spheres Spectrometer (BSS) system, where each element has a particular response to neutrons [5-8]. These dosimeters usually have better detection efficiency in a wider energy range allowing a better dose assessment. As shows figure 1, by using the integral counts of the BSS system it is posible to unfold the neutron spectra by using several methods like Montecarlo, parametrization and iterative procedures. With the neutron spectra information, that is multiplied by neutron fluence-to-dose conversión coefficients, different doses like dose equivalent Hp(10) or H*(10) can be estimated. The BSS response matrix, the count rates and the neutron spectrum are related trhough the Fredholm integro-diferential equation [9] which is an ill-conditioned equations system with an infinite number of solutions. The weight, time consumming procedure, the need to use an unfolding procedure and the low resolution spectrum are the BSS system drawbacks. Each of the mentioned difficulties have motivated the development of complementary procedures such as maximum enptropy, Genetic Algorithms (GA) [10, 11] and Artificial Neural Nets (ANN). In recent years, the use of ANN to unfold neutron spectra and to calculate equivalent doses from the count rates measured with BSS system has become in an alternative procedure in neutron specrometry and dosimetry [12-17].

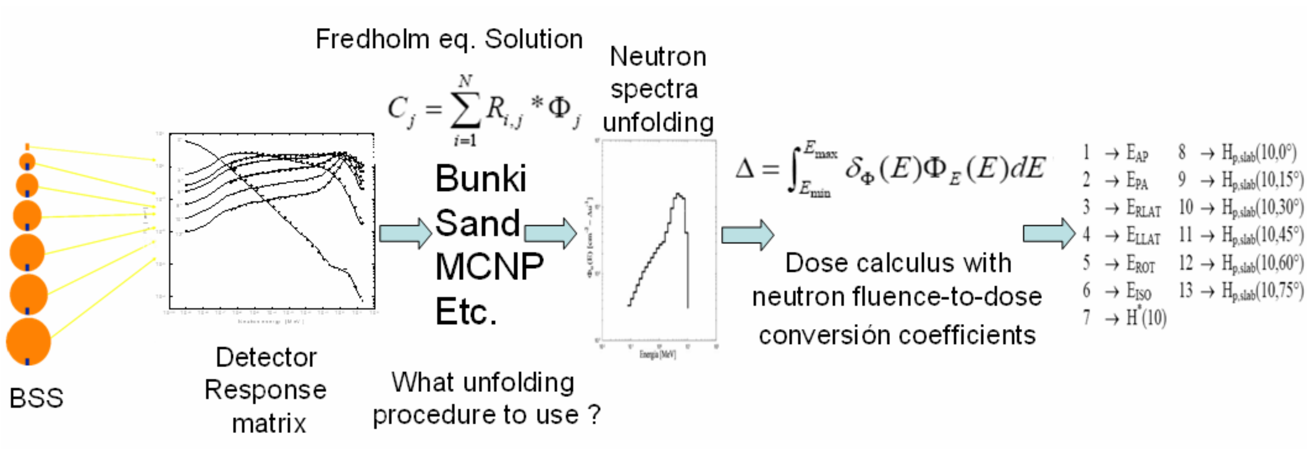


Figure 1. Neutron spectra unfolding and dose calculus traditional approaches

ANNs represent an area of Artificial Intelligence (AI), and are computational paradigms based on mathematical models that unlike traditional computing have a structure and operation that resembles the brain [18-23]. However, the choice of the ANN´s basic parameters (network topology, learning rate, initial weights, etc) often determines the success of the training process. The selection of these parameters follows in practical use no rules, and their value is at most arguable, because users have to choose the architecture and determine many of the parameters in a selected network by employing the trial and error technique. In ANN optimization for neutron spectrometry and dosimetry, statistical design and DoE methodologies were used for first time to develop a new systematic and experimental approach in order to design ANNs and their related structural and learning parameters, improving the network´s performance [24-27]. This approach was called Robust Design of Artificial Neural Networks (RDANN) methodology and was used to design, for first time, an ANN capable of unfold neutron spectra and to calculate simultaneouly 13 equivalent doses, in just one steep, providing the count rates of a BSS system as shows figure 2. Once the network's parameters were determined and the resulting ANN was trained, the neutron spectra and 13 equivalent dose calculus were obtained simultaneously in a few seconds, without the need of a long time consumming procedure, to choose an unfolding procedure, to solve directly the Fredholm equation, to use the neutron fluence-to-dose conversión coefficients for calculating the equivalent doses, a matrix response and an initial guess spectrum, as in the clasical BUNKIUT neutron spectra unfolding computer tool approach, overcoming the problems associated with such ill-conditionated problem.

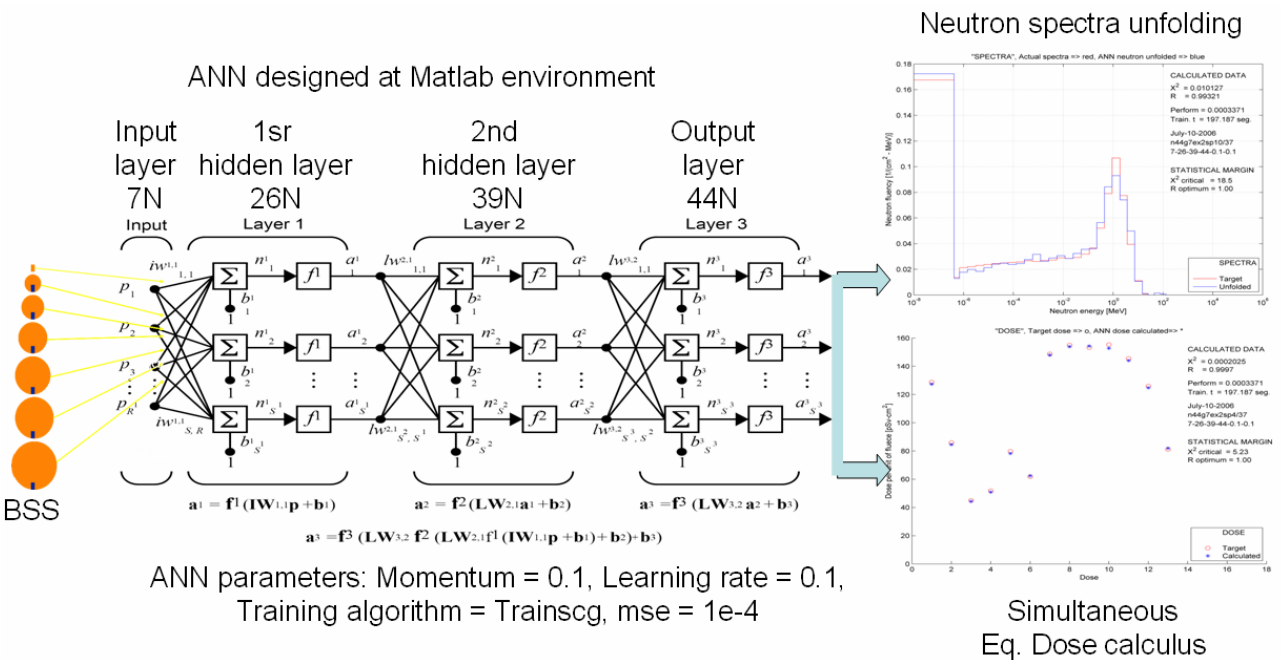


Figure 2. Neutron spectra unfolding and simultaneous dose calculus by means ANN

Once the ANN was designed, trained an tested within Matlab programming environment by means of RDANN methodology, the next steep was to extract the knowledge stored in the ANN's synaptic weights, in a matrix form, in order to design a computer tool based in the knowledge stored in this ANN. In this work, we believe for first time, is presented a new computer tool designed within Matlab environment capable to unfold neutron spectra and to calculate 13 equivalent doses.

## Materials and methods

An artificial network performs in two different modes, learning (or training) and testing. During learning, a set of examples is presented to the network. At the beginning of the training process, the network 'guesses' the output for each example. However, as training goes on, the network modifies internally until it reaches a stable stage at which the provided outputs are satisfactory. Learning is simply an adaptive process during which the weights associated to all the interconnected neurons change in order to provide the best possible response to all the observed stimuli. ANNs learn through training. There are various training algorithms for the different types of ANN. Based on the training the weights associated with each neuron adjust themselves. By training, it is meant that a set of inputs is presented repeatedly to the ANN and the weights adjusted so that the weights reach an optimum value, where optimum means that weights either tend to minimize or maximize. An ANN is trained repeatedly and at one point it reaches a stage where it has ‘learned’ a particular desired function. With proper training it can generalize, so that even new data, which was not part of the training data, will yield the desired output.

Figure 3 shows the matrix structure of the ANN designed by means of the RDANN methodology within Matlab programming environment. The ANN’s knowledge (synaptic weights) is stored in these matrixes. Figure 4 shows that once the ANN was designed the knowledge was extracted in several matrixes. With this information a computer tool was designed within Matlab environment. This tool is capable to show the results in a graphic way and to store the results in an excel sheet, for further data manipulation.

| Bias | Input layer | First hidden layer, second hidden layer and output layer | | | |
|---|---|---|---|---|---|
| [ 7x1 double] | [7x7 double] | [] | [] | [] | [] |
| [26x1 double] | [] | [26x7 double] | [] | [] | [] |
| [39x1 double] | [] | [] | [39x26 double] | [] | [] |
| [44x1 double] | [] | [] | [] | [44x39 double] | [] |

Figure 3. Synaptic weights matrix structure of the ANN designed-

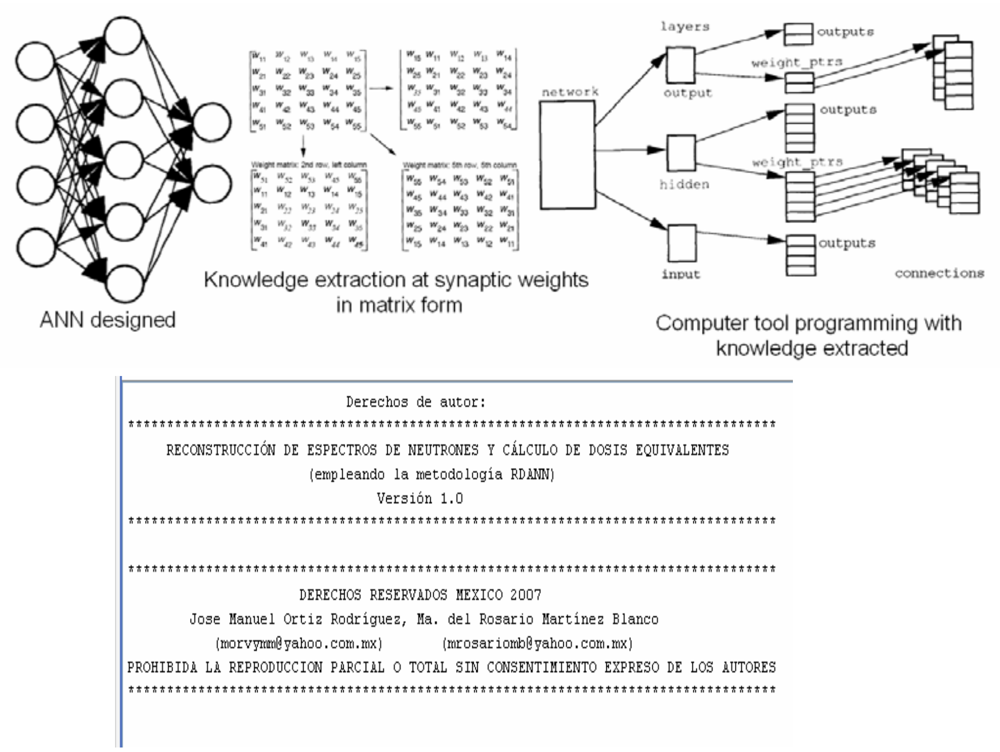


Figure 4. ANN knowledge extraction and computer tool design

## Results

An ANN is a collection of neurons in a particular arrangement or configuration. It is a parallel processor that can compute or estimate any function. Basically in an ANN, knowledge is stored in memory as experience and is available for use at a future time. The weights associated with the output of each individual neuron represent the memory which stores the knowledge. These weights are also called inter-neuron connection strengths. Each neuron can function locally by itself, but when many neurons act together they can participate in approximating some function. The knowledge that is being stored is also referred to as “numeric data”, which is transferred between neurons through weights. Matlab®, is a powerful programming software which has, so far been successfully used for solve ANN problems in engineering and scientific environments; in this work, for first time, the knowledge stored at ANN’s synaptic weights within Matlab was extracted in order to develop a customized software application. Figure 5 shows that when the program is executed, the only information required by the application, is the normalized count rates of the BSS system, contained in an excel sheet. Then the process continues automatically and, in a few seconds, the tool shows both a graph with the neutron spectra unfolded and a graph with 13 equivalent doses calculated together with an excel sheet containing the same information but with numerical data, for further manipulation.

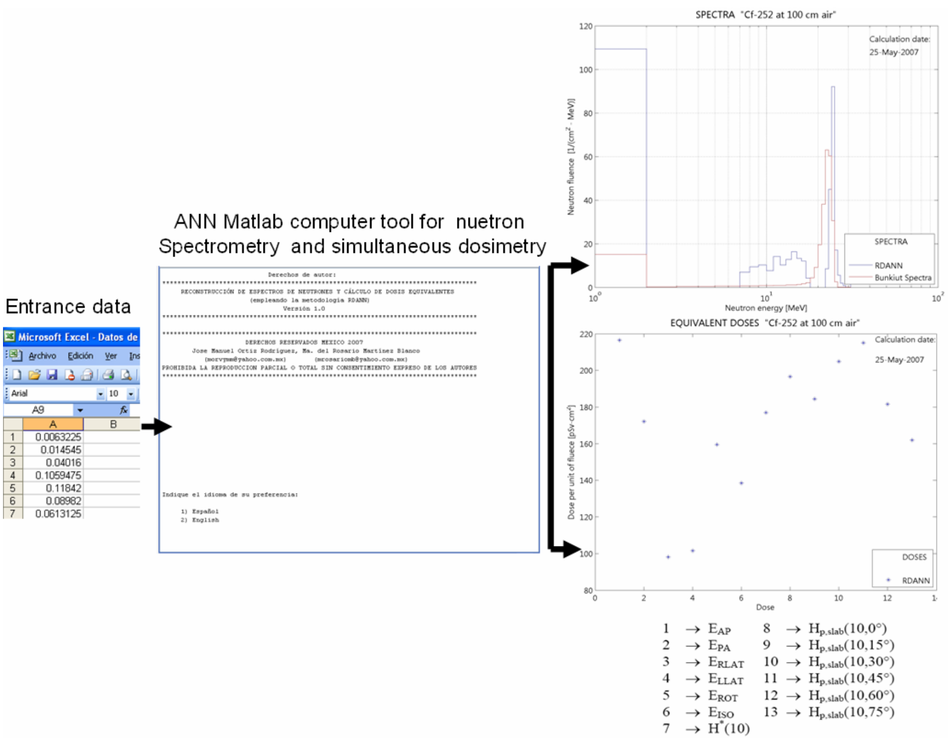


Figure 5. Neutron spectra and dose calculus computer tool designed with ANN technology

One experiment was carried out in order to verify the tool designed, comparing the results obtained with this computer tool against the results obtained with the BUNKUIT approach. A $^{252}$Cf neutron source was measured wit the BSS system, with the detector at 100 cm on air, and both methods were carried out comparing the results as shows figure 6.

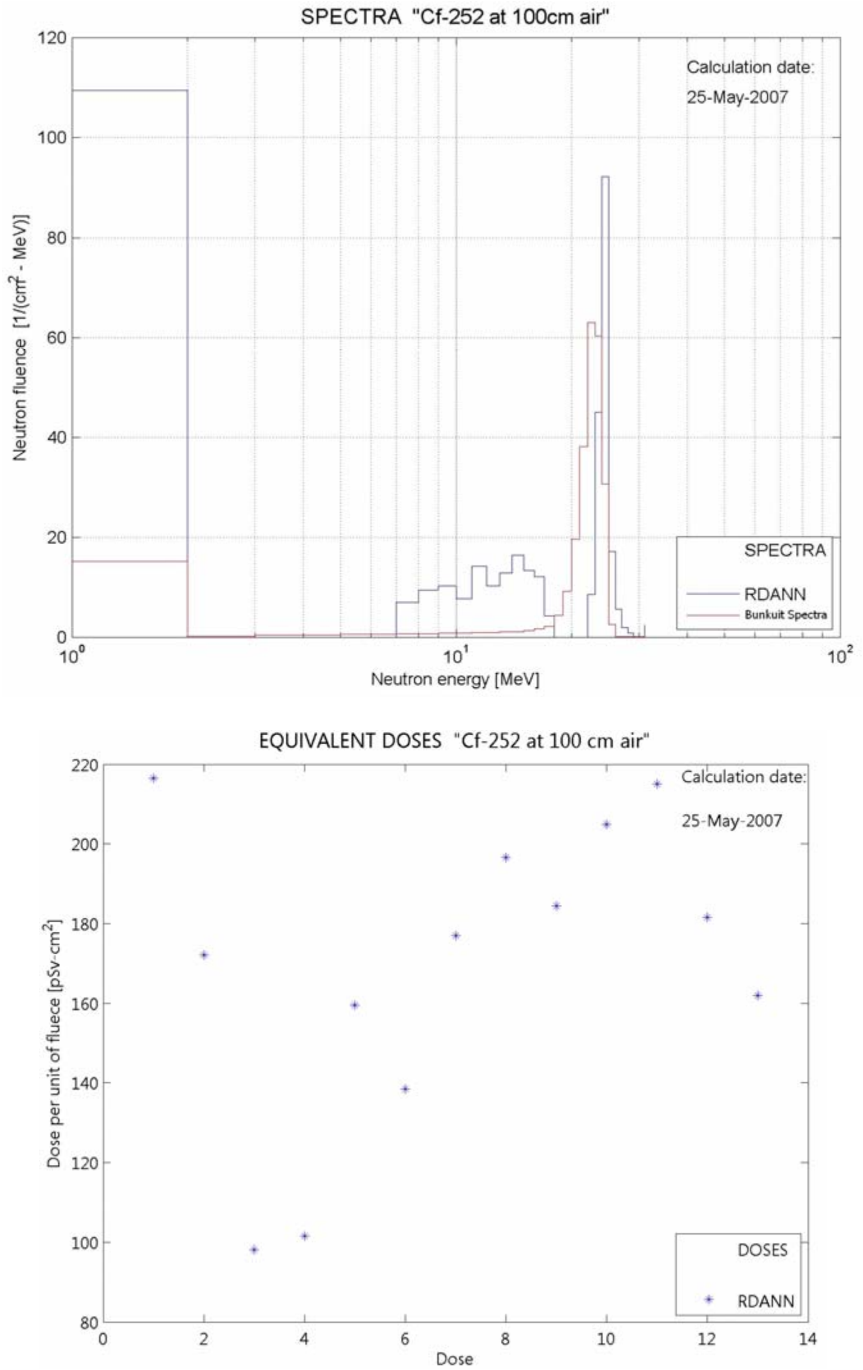


Figure 6. Neutron spectra unfolding and 13 equivalent dose calculus of a $^{252}$Cf source at 100 cm on air

## Conclusions

In this work, for first time a new computer tool based on ANN tecnology was designed to unfold neutron spectra and to simultaneously calculate 13 equivalent doses within Matlab® programming environment. The proposed computer tool reduces significantly the time required to prepare, to process and to present the information, in an appropriate way to the researcher, if compared with the traditional approaches. This tool overcome some drawbacks of the classical methodologies, reducing the time spent in the entire neutron spectra unfolding and dose calculus processes.

Matlab, is a powerful programming software which has, so far been successfully used for solve ANN problems in engineering and scientific environments; however it presents some drawbacks which make undesirable the use of this programming language because of several inconveniences. The knowledge extraction of the synaptic weights realized in this work, as numerical data in a matrix way, makes possible the design of a customized graphical user interface outside of the Matlab environment. Work is being done to this respect.

Just one experiment was carried out with the computer tool based on ANN technology, to verify its effectiveness, and was not possible to observe whether this approach work properly. More experiments are required in order to verify the results obtained comparing them with another probed approaches.

The use of ANN technology is a useful alternative to solve the neutron spectrometry and dosimetry problems; however, some drawbacks must be solved in the ANN design process, such as the proper synaptic weight initialization, and the optimum ANN topology selection, in order to obtain the best results of this approach. At present research and development of tools in this sense is carried out.

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