MCNP-X code in radioactive particle tracking

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A method based on the principles of the Radioactive Particle Tracking (RPT) technique is presented. The basic principle of the RPT technique is to use an array of radiation detectors to locate a single radioactive particle inside a volume of interest [1]. Counts obtained by an array of detectors properly positioned around the unit will be correlated to predict the instantaneous positions occupied by the radioactive particle by means of an algorithm. In this work, an appropriate mathematical search location algorithm given by 3-layer feedforward artificial neural network (ANN) to determine the coordinates of the particle.

Principles of RPT technique

The determination of the coordinates of the radioactive particle is given by algorithms based on phenomenological approach, which consider the relation between the number of photons recorded by each of the detectors and the location of the particle. The counts registered in each detector during a time interval is expressed by Equation 1 [2].

$$C_i = \frac{T\nu A\phi\varepsilon_i(\mathbf{p},t)}{1 + T\tau A\phi\varepsilon_i(\mathbf{p},t)}, i = 1, \ldots, n \quad (1)$$

Where T is the dwell time, τ is the dead time of the detectors, A is the source activity, ν is the number of photons emitted by disintegration, ϕ is the photopeak-to-total ratio and $\varepsilon_i(\mathbf{p},t)$ is the efficiency of i^{th} detector with respect to a position p in a time t. Besides the distance to the particle, the number of photons recorded depends on the attenuation properties of the materials disposed between the particle and the detector, and on the properties of the detector.

Methodology and Results

Simulated geometry was performed with the MCNP-X code, and it consists of a Polyvinyl Chloride tube containing air in its interior, four 2x2” NaI(Tl) detectors and the ^{137}Cs radioactive particle (RP). The four detectors were distributed in one plane around the tube at z = 0 cm and they are spaced at a 90° angle from each other. The distance between the detectors and the tube is 20 cm, as shown in Figure 1.

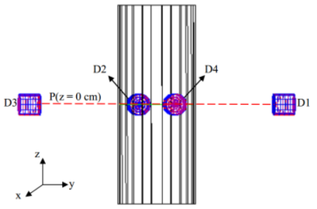

Figure 1. Simulated geometry

The data set of training was 60% Training, 30% Test, 10% Validation. RP was positioned in 36 different positions x and y. ANN inputs are the registered counts of the four detectors and the ANN outputs are the positions of the RP. Only counts of the region corresponding to the photoelectric absorption were used. Figure 2 shows the prediction of coordinates for Validation set. It is possible to observe the tendency of ANN to follow the coordinate’s values given by the MCNP-X code.

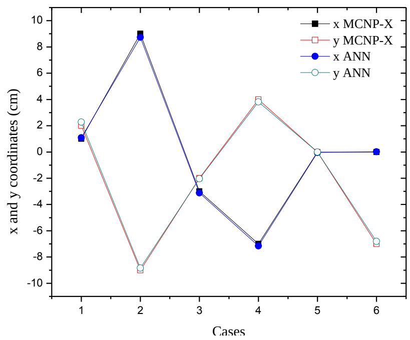

Figure 2. Validation set of the ANN

For x and y coordinates, over 80% of the cases were below 10% of relative error. The correlation coefficient was 0.99 for all cases. The results presented by the ANN indicates its great potential to predict the instantaneous position of the RP and it allows to continue the study for three dimensions.

References

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