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SCINTILLATION DETECTORS BASED ON NaI:Tl WITH 3% RESOLUTION IN CLASSIFICATION TASKS USING NEURAL NETWORKS

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СЦИНТИЛЯЦІЙНІ СЕНСОРИ НА КРИСТАЛІ NAI:TL З 3% РОЗДІЛЬНОЮ ЗДАТНІСТЮ В ЗАДАЧАХ КЛАСИФІКАЦІЇ НЕЙРОННИМИ МЕРЕЖАМИ

У роботі розглянуто використання нейронних мереж для обробки гамма-спектрів, що призводить до покращення процесу ідентифікації ізотопів та зменшення часу, необхідного для аналізу. Це забезпечує більш високу точність ідентифікації ізотопів, швидшу та більш автоматизовану, оскільки не вимагає повторного процесу розкладання та реконструкції спектра.

In the paper using of neural networks for processing gamma spectra leads to an improvement in the process of isotope identification and a reduction in the time required for analysis are considered. It allows for a higher accuracy in isotope identification, faster and more automated, as it does not require the repetitive process of spectrum decomposition and reconstruction.

Keywords: energy resolution, neural networks, nucleus.

Modern gamma spectroscopy provides unique opportunities for conducting various studies in many areas of knowledge. The main task of spectroscopic measurements is to determine the energy, intensity of discrete gamma lines from various gamma sources, their identification, and localization. Such studies are often carried out using scintillation detectors based on inorganic crystals such as NaI:Tl, CsI:Tl, and others. These detectors are widely used due to their high sensitivity and good operational properties. However, the insufficiently high energy resolution of scintillation detectors (SD) based on inorganic crystals (at best 6-7% for gamma quanta with an energy of 662 keV) does not allow solving many of the above-mentioned tasks to the fullest extent.

There are many ways and already implemented software products with classical approaches for processing radiation spectra. However, a relevant and actively developing issue today is the question of applying the paradigm of artificial neural networks for this purpose [1].

A successful solution to the problem of isotope identification using neural networks has been presented in the work of Ukrainian scientists A.V. Kochergin and S.S. Pivovarcev [2]. Based on the recommendations of these authors, a method of identifying radionuclides using a three-layer feedforward neural network was used.

The authors [2] draw attention to the fact that the temporal constraints of the measurement and identification procedure lead to the fact that in most cases the resulting gamma spectrum has a complex character with a significant number of multiples. These multiples are difficult to identify at real count rate levels that are only slightly higher than the detector's background load. The number of simultaneously identified isotopes cannot be large, so it is recommended to limit the number of simultaneously identifiable nuclides. To overcome the alone-stated problem, it was decided to use a multi-pass identification procedure with a NaI:Tl crystal detector, and a neural network architecture using the Sequential class from Keras. To construct the neural network, one hidden layer of neurons was defined and the activation function of the output layer with one neuron and a sigmoid activation function was determined. The model was compiled using a binary cross-entropy loss function, the Adam optimizer, and accuracy as the metric. The model was trined using the fitting method. We calculated the predictions. The output was an array of predicted probabilities for each input vector with values ranging from 0 to 1. The developments were carried out in Python, using libraries for scientific data processing, such as Keras, Theano, Tensorflow, and others.

An artificial neural network trained on the simple linear spectra showed results close to 95% for identifying individual nuclides. However, identifying nuclides with complex linear spectra yielded ambiguous results. To further develop the identification method, it was decided to use a NaI:Tl crystal detector spectrum with 3% resolution and isolate the energy range of interest to build and train a separate artificial neural network for it.

Figure 1 shows the radiation spectrum obtained by the crystal detector of dimensions 25x25 mm. The energy resolution at the peak of full absorption is 8.6%. The processed spectrum is shown in Figure 2, with an energy resolution at the peak of full absorption as 3.3%.

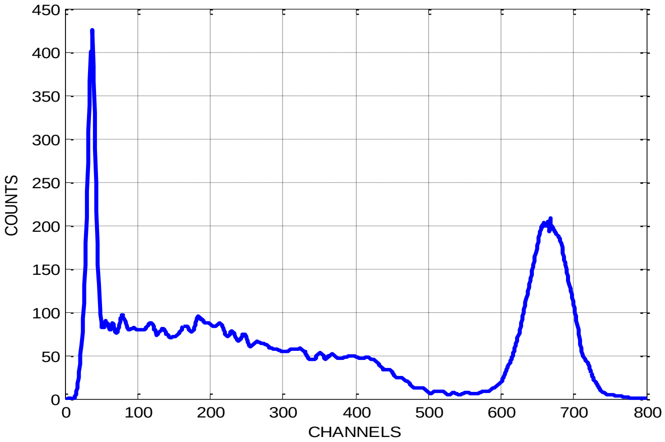

Fig.1. Radiation spectrum Cs^{137}.

To obtain the NaI:Tl crystal detector spectrum with 3% resolution, an algorithm for obtaining and analyzing the fine structure of the detector's output pulses was proposed [3.4]. A mathematical model was assigned to each scintillation pulse. The idea of further research was to decompose (cluster) the set of pulses into groups based on the shape of each pulse. Similar events, such as those with similar attenuation, combustion characteristics, maximum amplitude, etc., were selected for each group. The mathematical measure of similarity was a norm, the choice of which allows controlling the criterion for group formation.

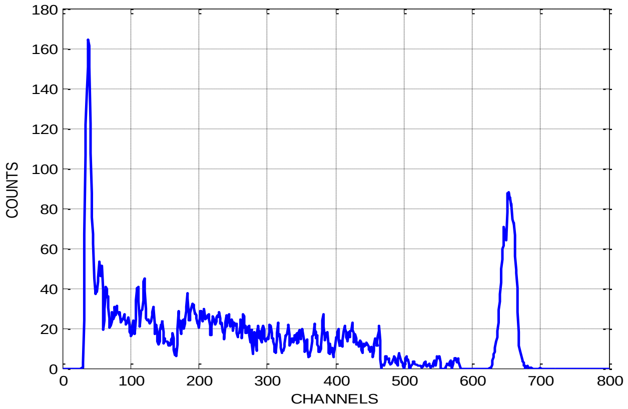

Fig.2. Gamma spectrum obtained on the crystal after processing.
The energy resolution at the peak of total absorption is 3.3%.

Using a neural network to identify the isotope Ba133 based on the NaI:Tl crystal detector spectrum with 3% resolution yielded results close to 100%. Identifying nuclides with complex linear spectra showed results close to 40%.

The multi-pass identification procedure method is a good approach for addressing problems associated with a large number of multiplexes in the gamma spectrum. The binary cross-entropy loss function and Adam optimizer are common choices for training neural networks, as they show good results in most machine learning tasks.

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