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Feasibility Study of 3D CNN-Based Angular Positioning of Radioisotope Using 8×8 SiPM array

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Radioisotope detection and gamma spectroscopy such as identification and quantification play crucial roles in various fields, including nuclear non-proliferation, nuclear decommissioning, and nuclear security. To date, three main types of detectors have been utilized for the position detection and gamma spectroscopy analysis of radioisotopes: (1) collimator-based gamma cameras, (2) multi-detectors based on two or more PMTs (Photomultiplier Tubes), and (3) CZT (Cadmium Zinc Telluride) detectors using coded aperture. While these detectors possess sufficient performance to achieve their objectives, their large volume reduces efficiency in field applications. Moreover, there is a disadvantage in that the position detection performance of some detectors is restricted to only one direction.

The 8×8 cerium-doped lutetium yttrium oxyorthosilicate (LYSO) crystal array coupled one-to-one with an 8×8 SiPM array is a detection assembly system consisting of a small detector with 64 channels. Consequently, from this detection system, 64 spectra can be obtained via multi-channel analyzer. Additionally, the LYSO crystal, acting not only as a scintillator but also as a radiation shield, results in varying spectrum distributions for each channel due to attenuation by the interaction of the scintillator and radiation. These characteristics are dependent on scintillators, types and positions of the radioisotopes.

This study conducted a feasibility study of a 3D CNN-based angular position detection method. The gamma detector used was composed of a crystal block of an 8×8 array of 3×3 x 20 mm3 LYSO and a 64-channel SiPM array (S14161-3050AS-08, Hamamatsu). The output signals were processed by digitizer (DT5202, CAEN), and transmitted to a computer using Janus DAQ software (CAEN). By varying the types of radiation sources (137Cs, 22Na, 60Co) and the angular positions (0°, 15°, 30°, 45°, 60°, 75°, 90°), spectra with minimal statistical fluctuation were obtained through long-term measurements. Additionally, a dataset was constructed by sampling based on Numpy.random.choice in the Python environment for the data augmentation. The results of testing the model using the dataset obtained from experiments revealed that, despite a slight gain shift applied, the angular positions of all radioisotopes were accurately detected. These findings demonstrate the feasibility of applying radioisotope detection and gamma spectroscopy utilizing 3D spectra data acquired from the SiPM assembly system in practical field settings.

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