NEURAL NETWORK ALGORITHMS FOR MONOLITHIC PET DETECTOR BLOCKS

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We are developing a high sensitivity Positron Emission Tomography (PET) scanner for human brain studies, to be used in a clinical environment. It should be compatible with a magnetic resonance imaging (MRI) scanner, in order to obtain a combined PET/MR image.

The proposed BrainPET scanner is based on gamma radiation detection with monolithic blocks of Cerium-doped Lutetium-Yttrium Orthosilicate (LYSO:Ce), coupled to arrays of commercial Avalanche Silicon Photodiodes (APDs). The introduction of monolithic crystals has a number of potential advantages, such as higher sensitivity, better energy resolution, continuous coordinates and intrinsic Depth of Interaction (DOI) correction. The light distribution generated on the LYSO block allows, by means of a positioning algorithm, the determination of the impinging position of the 511 keV photons. Several positioning methods, from the simplest Anger Logic to more sophisticate supervised learning Neural Networks, can be implemented to extract the incidence position of gammas directly from the APD signals. By replacing the classic PMTs by APDs, not only a more compact detector is obtained, but also a system which works properly under intense magnetic fields. As a consequence, this detector technology allows the possibility of obtaining simultaneous functional (PET, fMRI) and anatomical (MRI) images.

The BrainPET scanner will be composed of 4 rings of 52 detector blocks. Each block is made of two trapezoidal monolithic scintillators, individually covered and coupled to a pair of Hamamatsu S8550 APD arrays. Every matrix will have an individual front-end electronics readout, based on an Application Specific Integrated Circuit (ASIC). A more detailed description of the front-end electronics used for each PET detector block can be found in [1].

A search and effective implementation of the optimum positioning algorithm for the monolithic blocks has been developed. With this aim, both simulation and laboratory data were analyzed. The final goal of this study was to acquire enough knowledge about positioning algorithms, especially Neural Networks, to be able of implement our own process of training and evaluation of the tomographic setup available at CIEMAT. Furthermore, the long term objective is to provide event positioning on the full BrainPET scanner.

Perpendicular and slanted incidence of 511 keV gammas over a LYSO:Ce block were simulated using GAMOS 2.0.2, a CIEMAT Geant4-based simulation software [2]. The error distribution was histogrammed for several positioning methods. Optimal resolution was achieved with a two-step Feed Forward Neural Network. Its full width at half maximum (FWHM) value means an improvement over the second-best results of 42 % for perpendicular incidence and a 40 % and 39 % for transversal angles of 13.84^{o} and 31.14^{o} respectively (Fig. 1).

Two Neural Networks should be implemented for each monolithic block, so that the transversal and longitudinal impinging coordinates are independently estimated from the scintillation light measured along rows and columns of the APD matrix. The network structure consists of eight inputs, two hidden layers of four sigmoid shaped neurons each one, and one linear output neuron, which provides the transversal or longitudinal coordinate

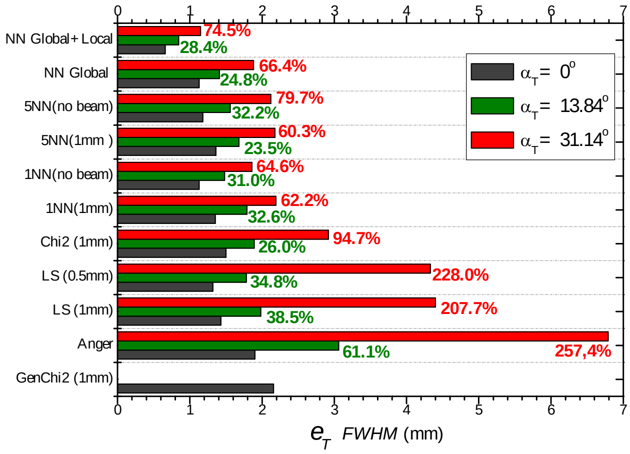

Fig. 1. Transversal spatial resolution for three transversal incidence angles α_T for several positioning methods. Variations with respect to normal incidence are also reported as percentage values.

A first BrainPET demonstrator has been developed at CIEMAT, based on two monolithic blocks working in coincidence and a rotary platform placed between them. Tomographic images of 0.25 mm and 1 mm diameter point ^{22}Na sources were acquired with this laboratory setup. The image resolution reached was 2.5 mm FWHM or better, starting from a resolution at detector level of ~2mm (Fig. 2). On the other hand, the system is able to distinguish different emitting points separated above 3 mm [2].

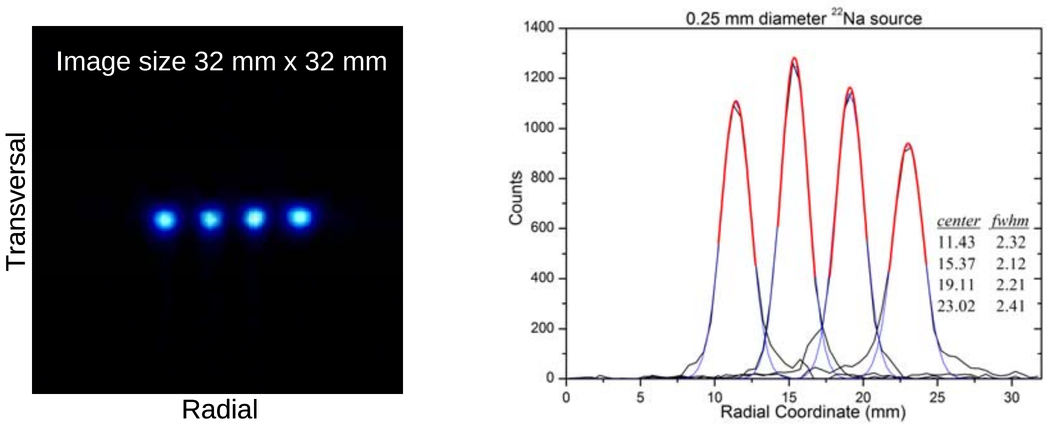

Fig. 2. Left: Four superposed images of a 0.25 mm diameter ^{22}Na point source acquired at 4 mm steps. Right: Intensity profile along the radial line which crosses the sources centres.

References

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