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(G*) Development and Implementation of a Machine Learning Algorithm for Pulse Shape Discrimination

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In any application where a radiation detector is utilized in a mixed radiation field, there is an inherent issue of separating the signal from the background. This research focuses on the separation of neutron and gamma-ray events in a liquid scintillator. The standard solution to this issue leverages the fact that the secondary particles generated in neutron and photon interactions are different; the former being nuclear recoils, typically protons in organic scintillators, and the latter being electrons or positrons in the case of pair production. The charge deposition characteristics of these secondary particles provide the basis for Pulse Shape Discrimination (PSD) as a means of event classification.

The work presented focuses on the development of a machine learning algorithm for use in the problem of pulse shape discrimination. The signals generated from gamma ray and neutron interactions inside the liquid scintillator used are comprised of three characteristic scintillation decay times: 3.16 ns, 32.3 ns, and 270 ns. The proportion of scintillation light generated from these three characteristic times is dictated by the stopping power of the particle traversing the scintillator, generating distinguishable signals for photon interactions relative to neutron interactions. Typically PSD is performed by allowing two different charge collection windows and comparing the amount of charge collected in both; tail-to-total integration. This work utilizes current generation machine vision algorithms for the task of event classification, where the PMT output from the scintillator will be utilized as the input to the machine vision algorithm. Current generation algorithms allow for feature extraction performed simultaneously at differing spatial extents, which enables the algorithm to extract valuable information about the signal from all three time scales present in the scintillator, 3, 30, and 300 ns. This new application of machine vision algorithms will be coupled with a current generation digitizer operating with 12 bit precision and sampling at 3.2 GS/s. This opens up the possibility of utilizing information from the rising edge of the signal, which is on the order of a few nanoseconds.

Training of this algorithm was performed in a supervised manner, which requires that labeled sets of data be provided for the algorithm to learn from. Any improperly labeled data utilized, diminishes the performance of the algorithm, making correctly labeled data paramount to success. Performing this for neutron and gamma-ray events in the scintillator is quite difficult due to the complications mentioned for event classification. The solution used in this project is to utilize an isotopic source of neutrons, PuBe. The PuBe source produces prompt gamma rays in conjunction with neutrons in some decays, with energies greater than 4 MeV. These prompt gamma rays can serve as an event trigger for detection of neutrons in a secondary detector, providing relative certainty that detected events within an appropriate time window are indeed neutron events. Producing a high degree of purity in the training data.

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