SIGNAL NOISE FILTERING TECHNIQUES IN RADIATION DETECTION APPLICATIONS FOR NEUTRON GAMMA PULSE SHAPE DISCRIMINATION

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ABSTRACT

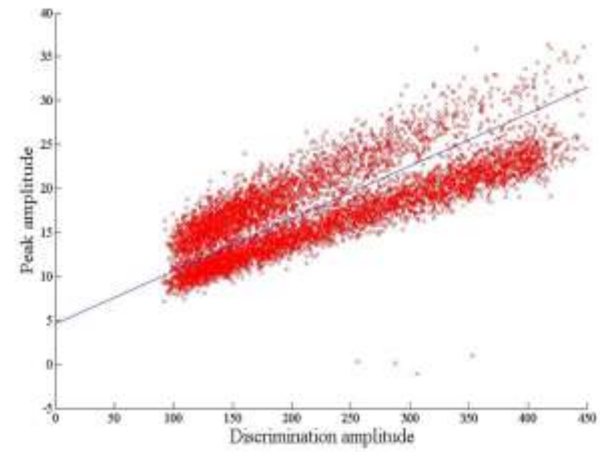
Neutron radiation often occurs as a result of radioactive decay and is accompanied by gamma radiation. This results in a mixed radiation environment comprising photons (gamma rays) and neutrons. Organic liquid scintillators are popularly used to detect both neutrons and gamma rays, where pulse shape analysis determines whether the event was caused by a neutron or a gamma-ray based on the decay characteristics of the pulse. Bespoke fast digitisers are currently widely used with organic liquid scintillators to record the pulse shape as digital samples. Pulse shape has high impact on pulse shape discrimination, especially in low energy region as it is generally difficult to discriminate a neutron event from a gamma-ray event. The quality of the discrimination of detected event is primarily determined by the quality of the pulse shape recreated using digital samples, as the discrimination is based on the characteristics of the pulse. The pulse signal is usually altered by signal noise and, the purpose of this paper is to select the best candidate for signal filtering technique to remove such high frequency noise components. It is important to ensure that the signal filtering technique is not consuming much of the processing power of the system and, it can be easily implemented in a real-time system.

Filtering Techniques

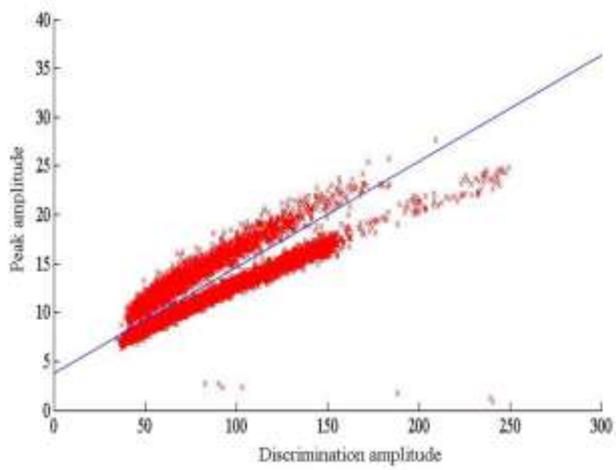
Three different digital filters were considered and the filtering performance was investigated with help of the quality of the pulse shape discrimination characteristics. The Butterworth filter is a simple filter which has a discrete-time system. It is an infinite impulse response digital filter, which is recursive with less memory requirements, fewer design limitations and lower computational difficulty than finite impulse response digital filters. The Butterworth filter uses the concept of the band-pass filters, which only allow a certain range of frequencies to pass. The Window Sinc is a finite impulse response filter that is executed in discrete time; a desired magnitude response is estimated in the digital time domain. Finite impulse response filters are mainly restricted to using discrete-time implementations. They approximate the magnitude response as well as the desired frequency response of the discrete-time system assuming a linear phase. The Moving Average Filter is widely used in digital signal processing applications, as it is reducing the random noise while keeping a sharp step response. The Moving Average is a finite impulse response, which depends on the number of filter taps and varying the weight of the coefficients. This means virtually any frequency response characteristic can be realised with a finite impulse response.

Results and Discussion

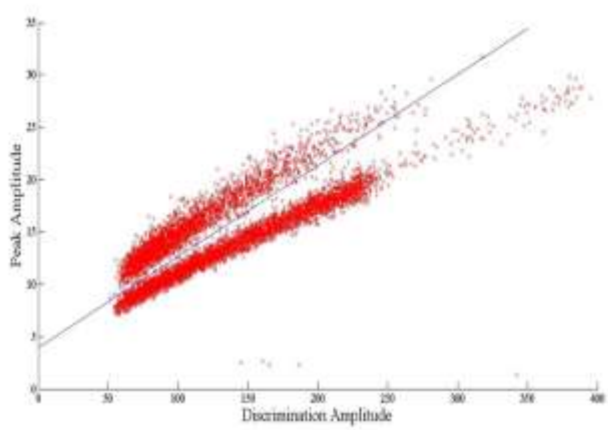
In this research, the Butterworth Filter, the Moving Average Filter and the Window Sinc Filter were tested in MatLab [1-3]. The pulse shape discriminations were programmed into producing histograms using previously calibrated line of separation for neutrons gamma rays. Pulse gradient analysis was used as the pulse shape discrimination technique, where it is based on a comparison of the peak amplitude and discrimination amplitude (amplitude of a sample occurring at a certain time interval after the peak amplitude) [4-5]. Figures 1a-1c are showing the pulse shape discrimination plots based on pulse gradient analysis for the cases of the Butterworth Filter, the Moving Average Filter and the Window Sinc Filter respectively.



a) Neutron gamma pulse shape discrimination for the case of the Butterworth Filter.



b) Neutron gamma pulse shape discrimination for the case of the Moving Average Filter.



c) Neutron gamma pulse shape discrimination for the case of the Window Sinc Filter.

Figure 1: Pulse gradient analysis based neutron gamma pulse shape discrimination for an americium-beryllium source data using different filtering algorithms.

Upper plume in each plot in figure 1 corresponding to gamma rays and lower plume corresponding to neutrons. Figure of Merits were estimated (as described in [4]) for the pulse shape discrimination results shown in figure 1, and hence the performance of the signal filtering was assessed. Example figure of merit histogram for the case of moving average filter is shown in figure 2.

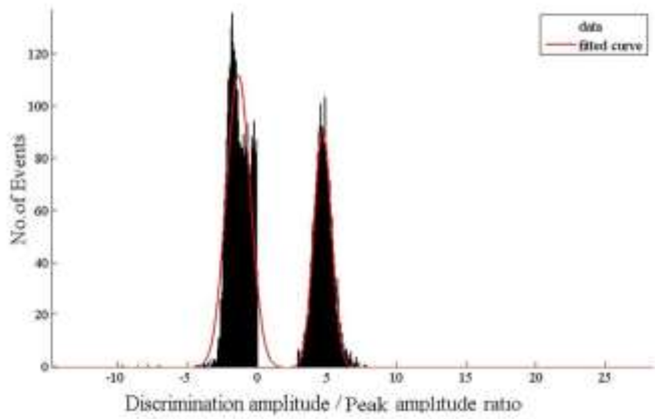


Figure 2: Figure of merit histogram for the case of moving average filter with americium-beryllium source data.

The figure of merit values for the moving average filter, the Butterworth filter and the Window Sinc filter are 1.727, 1.295 and 1.613 respectively. The moving average filter is showing the best figure of merit and the Butterworth filter is the least desirable. The Window Sinc filter was reliable at producing a good neutron gamma separation, but in numerical terms the figure of merit shows that the Window Sinc filter is not as good as the moving average filter. Also, considering the processing time and the implementation in a real-time system, the moving average filtering is a better technique compared to the Window Sinc filtering.

References

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