TSpectrum class developments

Miroslav Morháč, *Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia*

Introduction

•TSpectrum class of the ROOT system is an efficient tool aimed for the analysis of spectra (histograms) from the experiments in nuclear, high energy physics, etc.

•it includes non-conventional processing functions of

- background estimation, elimination
- deconvolution – resolution improvement
- smoothing
- peak identification
- fitting
- orthogonal transforms, filtering, enhancement

Background estimation

Goal: Separation of useful information (peaks) from useless information (background)

The method is based on Sensitive Nonlinear Iterative Peak (SNIP) clipping algorithm [1], [2]. It is implemented in Background1 and Background1General functions.

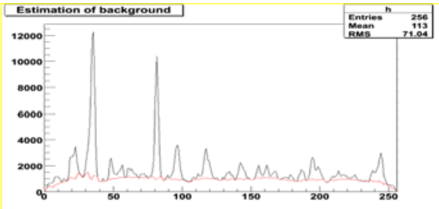

Fig. 1 Example of the estimation of background for number_of_iterations=6 and increasing window. Original spectrum is shown in black color, estimated background in red color.

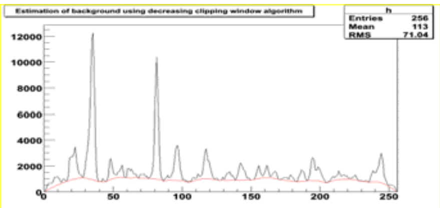

Fig. 2 Example of the estimation of background for number_of_iterations=6 and decreasing clipping window algorithm. Original spectrum is shown in black color, estimated background in red color.

Deconvolution

Goal: Improvement of the resolution in spectra, decomposition of multiplets

Mathematical formulation of the convolution system is

$$y(i)=\sum_{k=0}^{N-1} h(i-k)x(k),\quad i=0,1,2,\ldots\ldots,N-1$$

where h(i) is the impulse response function, x, y are input and output vectors, respectively. To solve the overdetermined system of equations we have employed Gold deconvolution algorithm [3], [4]. It is implemented in Deconvolution1 function.

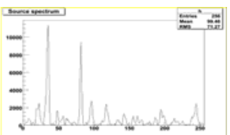

Fig. 3 Source spectrum

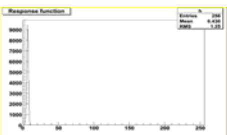

Fig. 4 Response spectrum

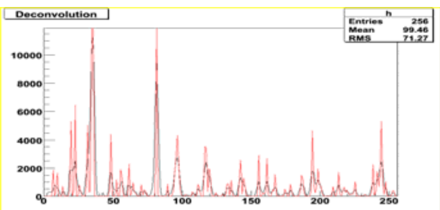

Fig. 5 Example of Gold deconvolution. Deconvolved spectrum is drawn with red color.

Boosted deconvolution

After preset number_of_iterations a boosting operation (exponetial function) is applied to the estimated solution and the Gold deconvolution is repeated [5]. It is implemented in Deconvolution1HighResolution function.

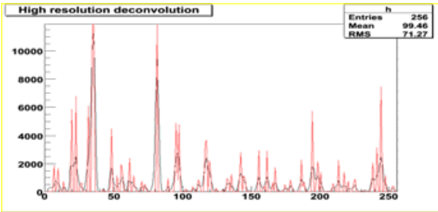

Fig. 6 Example of boosted Gold deconvolution. The original source spectrum is drawn with black color, deconvolved spectrum (200 iterations, 50 repetitions, boosting_coef=1.2) with red color.

Decomposition - unfolding

$$y(i)=\sum_{k=0}^{N-1} h(i,k)x(k),\quad i=0,1,2,\ldots\ldots,N-1$$

Decomposition unfolds source spectrum according to response matrix columns. It is implemented in Deconvolution1Unfolding function

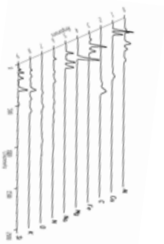

Fig. 7 Response matrix composed of neutron spectra of pure chemical elements

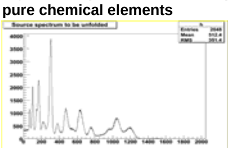

Fig. 8 Source neutron spectrum to be decomposed

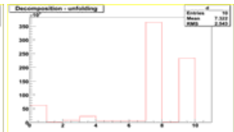

Fig. 9 Estimated coefficients correspond to contents of chemical components

Smoothing

Goal: Suppression of statistical fluctuations

The algorithm is based on discrete Markov chains [6]. It is employed for the identification of peaks in noisy spectra. It is implemented in Smooth1Markov function.

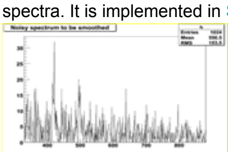

Fig. 10 Noisy spectrum

Fig. 11 Smoothed spectrum aver_window=10

Peaks searching

Goal: to identify automatically the peaks in the spectrum with the presence of the continuous background and statistical fluctuations - noise.

In the algorithm first the background is removed (if desired), then Markov spectrum is calculated (if desired), then the response function is generated according to given sigma and deconvolution is carried out. It is implemented in Search and Search1HighRes functions.

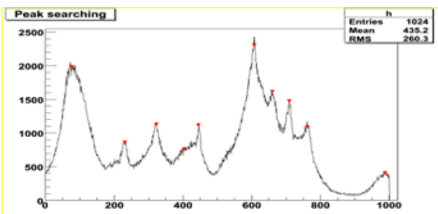

Fig. 12 Found peaks denoted by markers

Fitting

Goal: to estimate simultaneously peak shape parameters in spectra with large number of peaks

Two methods are employed:

➢algorithm without matrix inversion (AWMI), implemented in Fit1Awmi function [7, 8]

➢Stiefel – Hestens algorithm [9] (conjugate gradient based method), implemented in Fit1Stiefel function.

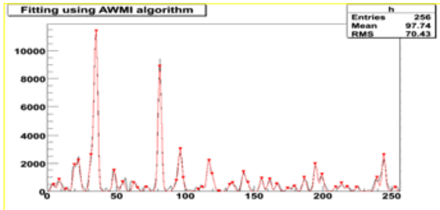

Fig. 13 Original spectrum (black line) and fitted spectrum using AWMI algorithm (red line). Positions of fitted peaks are denoted by markers

Transform methods

Goal: to analyze experimental data using orthogonal transforms

They can be used to remove high frequency noise, to increase signal-to-background ratio as well as to enhance low intensity components [10], to carry out e.g. Fourier analysis etc. We have implemented the function Transform1 for the calculation of the commonly used orthogonal transforms (Fourier, Walsh, Haar, Cosine etc.) as well as functions for the filtration (Filter1Zonal) and enhancement of experimental spectra (Enhance1).

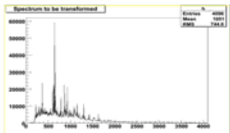

Fig. 14 Original gamma-ray spectrum

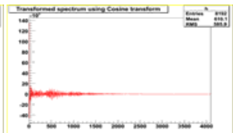

Fig. 15 Transformed spectrum from Fig. 14 using Cosine transform

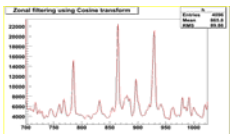

Fig. 16 Original spectrum (black line) and filtered spectrum (red line) using Cosine transform and zonal filtration (channels 2048-4095 were set to 0)

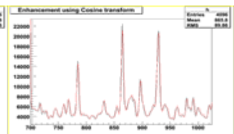

Fig. 17 Original spectrum (black line) and enhanced spectrum (red line) using Cosine transform (channels 0-1024 were multiplied by 2)

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