Signal and Data Analysis

Exercise 11

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1 Huffman Code

The file huffman-data.txt[1] contains data from the ALICE TRD detector.
The file is in text format with 30 numbers between 0 and 1023 per line, representing 30 samples from one channel of the TRD. The file contains more than 90 000 signals with 30 samples each from 1 200 events.
The data shall be compressed using the Huffman algorithm.

(a) Fill a histogram with the distribution of ADC values sampled in the data set. What are the 8 most frequent values and their frequencies?

(b) For the 8 most frequent values, build a Huffman tree and determine the Huffman codes for these symbols.

(c) Write a program to build the Huffman tree and determine the Huffman codes for a table of input symbols and their frequencies. Check the program by running it on the 8 most frequent values of the data sample.

(d) Using this program, determine the Huffman codes for all 1024 possible values in the input stream. To avoid the bit manipulations needed to transform the bit stream into a byte stream, encode the input stream into a stream of characters '0' and '1'.

(e) How many bits are needed for the encoded data? How many bits are needed to encode the data with the minimal fixed symbol length? Compress the file huffman-data.txt using the gzip and bzip2 programs and compare the resulting sizes with the uncompressed and Huffman-coded sizes.

(f) Decode the encoded data stream to confirm that the encoding was lossless.

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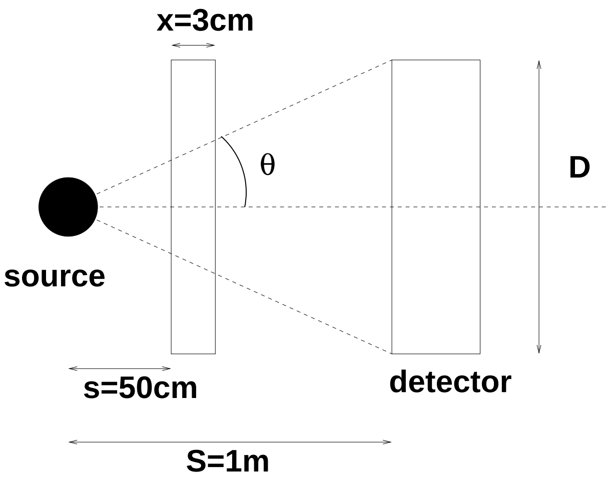
[1] available from http://qgp.uni-muenster.de/~weinheim/lehre/ss08/signals/huffman-data.txt.gz, the file is compressed, use gunzip to uncompress

2 Detector Simulation

Perform a Monte Carlo simulation of the following simplified experiment:



The detector setup corresponds to the setup in exercise 2 from sheet 10 with additional material between the source and the detector.
Photons of a fixed energy E_0 are emitted isotropically in the full solid angle (4π) from a point–like source. The photon detector gives a Gaussian–shaped energy response with a relative energy resolution $\sigma_E = \Delta E/E = 0.1$. The detector is a disc with a diameter D at a distance S=1m to the source.
A piece of material is placed between the detector and the source, at a distance of 50 cm from the source, with the same diameter as the detector and a thickness of 3 cm. The mean free path of the electron in the detector material is λ=1 cm. In case of an interaction, the electron loses a uniform fraction of its energy [0,E_γ].

(a) Simulate the detection probability and the measured energy spectrum for the case that the interaction does not alter the electron's direction.

Determine the probablity for an interaction in the material. Generate a sample of electrons and determine for each electron if it interacts with the material and where the interaction occurs. Allow for multiple interactions in the material, taking the reduced energy in the subsequent interactions into account.

(b) Repeat the simulation from (a) for the case that the scattered photon changes its direction by a random angle. The polar scattering angle shall be normally distributed with a mean of 0° and a width of 30°, while the azimuthal component is uniform.

Dice the distribution of scattering angles. Determine the rotation matrix for the scattering angles and apply them to the momentum vector of an electron. Determine if the electron hits the detector and at which energy it will be measured.

How do detection probablity and energy resolution change with respect to case (a)?