NE 204: Advanced Concepts in Radiation Detection and Measurement

Experiment 0: Energy Calibration with Reproducible Workflows

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Purpose

The purpose of this "experiment" is to provide the opportunity to practice generating lab reports using the reproducible workflow required for this course. Energy calibration of a HPGe detector (a ubiquitous task in radiation detection laboratories) will be used as an example for practicing the workflow. You must implement an approach to downloading data (see next section), extract the spectral information, and use it to develop a model for energy calibration. The energy calibration will then be evaluated using (at least) one of the datasets that was not used in the calibration procedure. These results, along with any relevant discussion, are to be included in the lab writeup.

Approach

This is not a real lab in the sense that you will not be collecting data yourself. The purpose is to practice writing lab reports, so data for the task of energy calibration will be provided to you. Of course, students are welcome to collect their own callibration spectra from any of the available HPGe detectors, but the emphasis must be on fulfilling the software-related tasks discussed below.

Data

The data used for this experiment has already been collected. It consists of pulse height spectra taken with a coaxial HPGe detector using 5 different radionuclide calibration sources: ^{241}Am, ^{133}Ba, ^{137}Cs, ^{60}Co, and ^{152}Eu. The MCA with which the data was collected had 13-bit resolution, yielding 8192 channels. The data for all five pulse height spectra are stored in a single text file in ASCII format. The first row of the file is a header indicating which radionuclide the data in the columns correspond to, followed by 8192 rows indicating the number of counts measured in each MCA channel. The link to the data file and the corresponding md5 checksum are available at:

- **Data:** `https://www.dropbox.com/s/hutmwip3681xlup/lab0_spectral_data.txt?dl=0`
- **Checksum:** `https://www.dropbox.com/s/amumdrm9zp1kn8d/lab0_spectral_data.md5?dl=0`

Required

- Implement the `data` command in the `Makefile` such that the data at the above link will be downloaded when the user types `make data`. *Hint: take a look at* `wget` *or* `curl` *- command line tools used for downloading files.*

Optional

- Implement a `validate` command in the `Makefile` that will compute the md5 checksum for the downloaded data, and compare it against the provided checksum to verify that the data has not been corrupted. *Hint: the* `md5sum` *command with the* `-c` *flag might prove useful.*

Analysis

Once the calibration data has been successfully downloaded, the energy calibration can be done. The first step will be to load the calibration data into IPython *Hint: check out* `np.loadtxt`. The next task is to determine the centroids of the peaks in the pulse height spectrum that correspond to known gamma-ray energies *Hint: your experience with* `scipy.optimize.curve_fit` *from the first lab session should prove useful here.* Finally, once the parameters of the energy calibration model have been determined, the quality of the calibration should be evaluated by applying it to one of the pulse height spectra that was not used in the calibration procedure. Compare the calibrated peak locations to their "true" values as specified in the nuclear data literature. To minimize the amount of effort required for the calibration itself, the following procedure is proposed:

Required

- Conduct a two-point, linear energy calibration using the 59.541 keV peak from ^{241}Am and the 661.657 keV peak from ^{137}Cs.
- Apply the linear calibration model to the ^{133}Ba dataset and quantify the difference between the calibrated peak locations and the expected peak locations based on the literature.

Optional

- Use more than two points to determine the parameters of the linear calibration model via regression methods.
- Use data from the other sources (e.g. ^{152}Eu) to evaluate the energy calibration.

This analysis should result in the production of *at least* one figure that will be included in the report. The generation of these figures should be automated by implementing the `analysis` command in the `Makefile`.

Testing

Required

- Design and implement *at least one* unit test for your data analysis code.

Report

Make sure to update the project `README.md` with instructions for how to download the data, replicate your analysis, run your software test suite, and generate the document. The report itself should contain the following:

1. Describe the motivations and goals of this experiment. Why is energy calibration of detectors important?

2. Discuss the approach to the energy calibration (N.B. there is no "experimental setup" in this case).

3. Present the results of your energy calibration and include any relevant discussion.