Project Title
The development of Sparse, Nonlinear Signal Processing Techniques for Removing Microphonic Noise from Nuclear Detector Measurements

Project Reference Code: DNDO-LANL-Mascarenas

Hosting Site
Los Alamos National Laboratory
Los Alamos, NM

Project Description
Germanium Detectors are generally considered the gold standard in making measurements of nuclear events with high energy spectrum resolution. For this reason they are very attractive for field-deployed nuclear detection and characterization. Unfortunately in order for these detectors to work the germanium crystal must be cooled to liquid nitrogen temperatures. Currently this cooling is achieved in one of two ways. The first technique involves using a dewar filled with liquid nitrogen to provide the necessary cooling to the crystal. The problem with this approach is that the dewar typically needs to be refilled every week. The refilling requirements make this approach impractical for nuclear detection applications that involve deployment in the field. The next common alternative is to use a piston-driven cryocooler to provide the necessary cooling to the germanium crystal. This option is attractive in that only a source of electrical power is needed to power the crycooler. However, this class of cryocooler can expose the nuclear detector to mechanical vibrations. When a germanium detector is exposed to mechanical vibrations microphonic noise tends to be introduced into the nuclear detector measurements.

The introduction of microphonic noise to the measurements tends to result in a loss of spectral resolution. Microphonic noise introduces some complications with respect to filtering from a signal processing point of view. The nuclear detection events of interest are generally broad-band spikes. In contrast the microphonic noise is typically sparsely represented in the Fourier domain, but not necessarily over a narrow bandwidth. When conventional linear signal processing techniques are applied to these measurements the result is that the amplitude of the spikes is inevitably distorted as well resulting in a loss in accuracy in the resulting energy spectrum measurement. Microphonic noise can also be introduced by other mechanical excitation sources in the environment (e.g. vehicles passing by, construction equipment, motors, wind). It is imperative to develop new signal processing techniques to remove microphonic noise from nuclear detector measurements.

The recent emergence of nonlinear, sparse signal processing techniques shows great promise for addressing the microphonic noise problem. Initial results have shown that these types of techniques can be used to decompose the nuclear detection measurement into spike components and Fourier components that correspond well with the nuclear detection signal and the microphonic noise signal, respectively. In the summer of 2015 a significant number of experimental measurements were obtained from an He3 tube exposed to the vibration environment of a piston-driven cryocooler. He3 tubes are also susceptible to microphonic noise. The next step is to begin implementing sparse low-rank matrix

decompositions, sparse imputation, and sparse blind-source separation techniques to this data for the purposes of removing the microphonic noise and improving the nuclear detection capability of cryo-cooled detectors.

Initial student results from the summer of 2016 give strong indication that this class of techniques can work to remove microphonic noise in such a manner that the amplitude of the spikes experience minimal loss in accuracy. We suspect for instance that part of the reason these techniques hold great promise is that the nuclear signal and the microphonic noise signal are highly statistically independent. We now need to verify these techniques work on our larger measurement dataset. The goal of this project is for the student to develop and apply a variety of sparse-signal processing techniques to nuclear detection data that we have already collected. Ultimately we want to document these results in a peer-reviewed journal paper. It is very possible that a motivated student could publish multiple journal papers during the course of this summer. The reason being that these techniques are relatively easy to implement and test using publically available software. It is just that this new class of techniques has not been applied to nuclear detector data outside our group to the best of our knowledge. However, this will require that the student is diligent in learning about sparse signal processing. We prefer to find a student with a signal processing background to execute this project.

Disciplines
Computer Systems Design (including Signal Processing)
Nuclear Engineering
Mechanical Engineering
Applied Mathematics

Mentor(s)
David Mascarenas, dmascarenas@lanl.gov, 505-665-0881

Internship Coordinator
Scott Robbins, srobbins@lanl.gov, 505-667-3639

The name and contact information of the hosting site internship coordinator is provided for further assistance with questions regarding the hosting site; local housing availability, cost, or roommates; local transportation; security clearance requirements; internship start and end dates; and other administrative issues specific to that research facility. If you contact the internship coordinator, identify yourself as an applicant to the DNDO Summer Internship Program.

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