SAND2022-14202D

Sandia National Laboratories

BALDR: Base Algorithms for Learned Detection of Radioisotopes

Tyler Morrow (PI) (tmorro@sandia.gov), Aislinn Handley, Paul Thelen, Alan Van Omen, Alyshia Bustos

Research priority: further investigate and improve the efficacy of machine learning applied to radioisotope identification (RIID) and related problems.

BALDR
Base Algorithms for Learned Detec6on of Radioisotopes

Research

Single-Isotope RIID	Single-Event RIID	RIID-related Problems
Mul6-Isotope RIID	Mul6-Event RIID	Synthesis

Development

PyRIID

GADRAS Plug-in

Static Synthesis Process Example

Computed

Foreground Rate (cps)	100
Foreground Counts	300
Background Counts	30

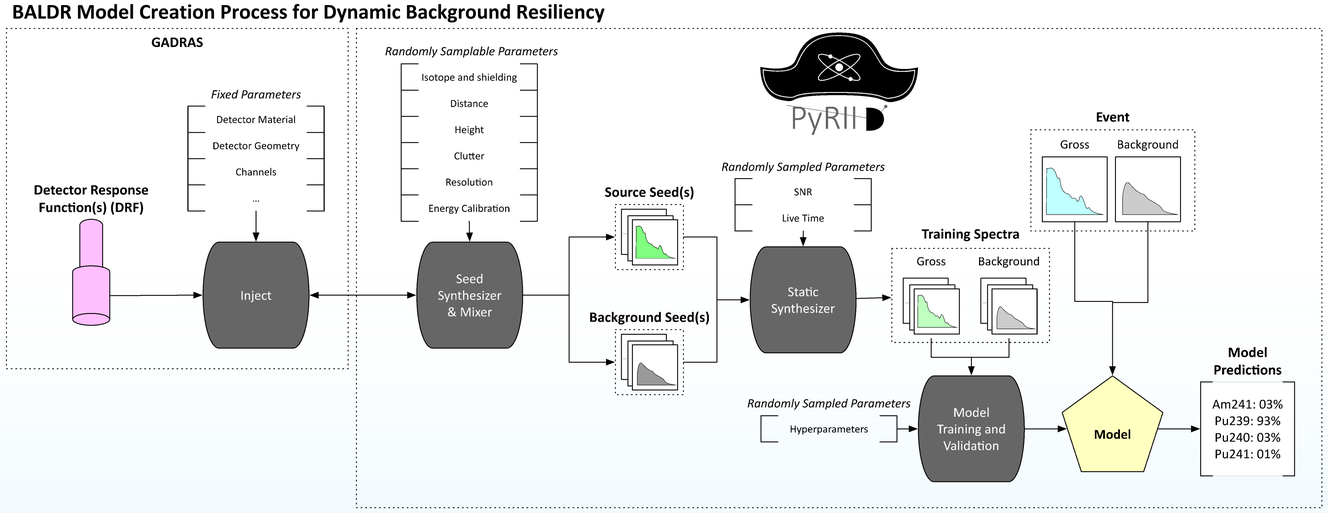
Randomly Sampled

Live Time (seconds)	3
SNR	10

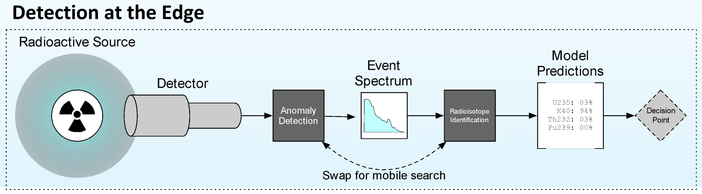
Fixed

Background Rate (cps)	10

BALDR Model Creation Process for Dynamic Background Resiliency



Detection at the Edge

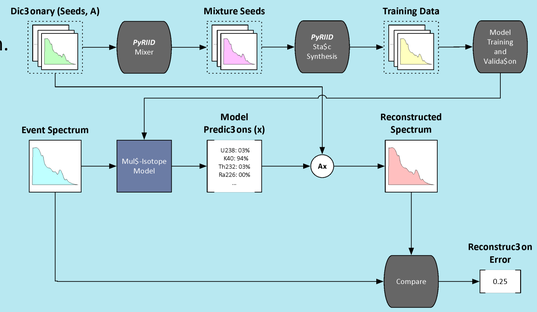


PyRIID is Open Source!
https://github.com/sandialabs/PyRIID

Recent Research Highlight for Multi-Isotope Identification[1]

Goals:
1. Estimate the proportions of isotopes present in spectrum.
2. Detect when an observed spectrum was not in training.

Method:
We trained a neural network with a *custom loss function* incorporating label proportion estimation and spectrum reconstruction.



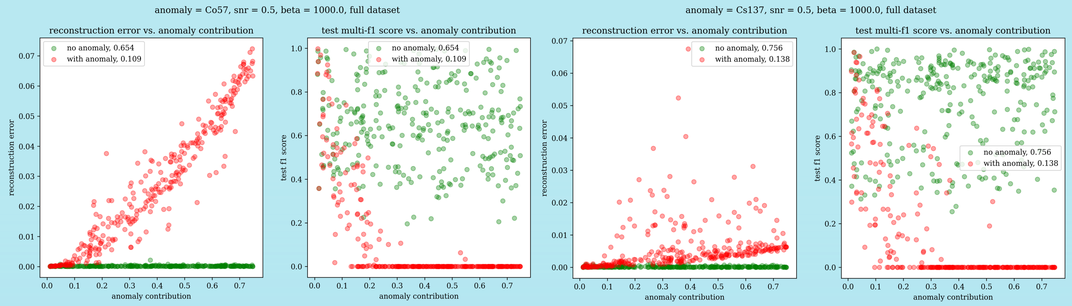
Detector:
3” x 3” Nal
(GADRAS 19.x “3x3/Nal MidScat”, distance: 450cm)

Custom loss function:

$$\min_{f} \sum_{i=1}^{n} L_{\text{sparsemax}}(\boldsymbol{\theta}_i, \boldsymbol{y}_i) + \beta \|\boldsymbol{x}_i - \boldsymbol{D} \cdot \hat{\boldsymbol{y}}(\boldsymbol{\theta}_i)\|_2^2$$

$L_{sparsemax}$
- Sparsemax loss (Martins, et. al., 2016) promotes sparse label proportions.
- Serves as an alternative to L1-regularization for probability distributions.

L_{RE}
- The reconstruction error of the original signal is penalized.
- This encourages consistency with the known dictionary.
- Provides a built-in novel source detection metric.



Conclusions:
1. Sparsemax loss consistently outperformed crossentropy loss.
2. Marginal performance gains were seen by adding a reconstruction penalty.
3. Reconstruction error could be an effective detector of novel sources (i.e., sources not present in training) if novel sources are sufficiently different, something more likely achievable with a smaller dictionary.

Next Steps:
1. Explore K-L divergence and Bayesian probability for reconstruction error.
2. Expand training diversity in non-isotopic dimensions.
3. Incorporate new model architecture and process formally into PyRIID.

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology &Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.
SAND No. _____

[1] Multi-isotope label proportion estimation work conducted by Alan Van Omen for BALDR in collaboration with his Thesis Advisor, Professor Clayton Scott, at University of Michigan.

Sandia National Laboratories