Reducing medical isotope nuisance alarms in radiation portal monitors
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Motivation
- Smuggling of special nuclear material (SNM) → deployment of thousands of radiation portal monitors (RPMS) at borders, shipping ports, airports
- RPMS alarm on presence of elevated radiation above background (gammas, neutrons)
- Types of alarms
  - Threat alarms (SNM, dirty bomb material): rare [1]
  - False alarms (natural background fluctuation): can be avoided
- Nuisance alarms (nuclear medicine patients, cargo containing naturally occurring radioactive material (NORM)): PROBLEMATIC!
  - 100,000s of nuisance alarms in United States annually [2]
  - Largest culprits are 90Sr/90Y (medical) and kitty litter (NORM) [3]
- Nuisance alarms processed with handheld spectroscopic radiation detectors → time, money
- Objective: RPM on-the-fly radionuclide identification → distinguish threat/nuisance

Previous Work
- Pedestrian and vehicle RPM prototypes using organic liquid scintillation detectors [4-5]
- Tested on SNM and other sources at European Commission Joint Research Centre in Ispra, Italy, and at Los Alamos National Laboratory
- Strengths: zero false alarm rate; reliable alarming on shielded neutron and gamma sources
- Weakness: radionuclide identification algorithm worked well for many sources, but struggled with low energy sources (137Cs, 241Am)

A New On-The-Fly Radionuclide Identification Algorithm Using Spectral Angular Mapping

![Fig. 2. Medical isotopes + pedestrian RPM at C.S. Mott Children’s Hospital](image)

![Fig. 3. Testing our pedestrian RPM at European Commission Joint Research Centre, Ispra, Italy.](image)

![Fig. 4. Pulse height distribution (PHD) for long measurement time with pedestrian RPM.](image)

- FFT converts CDF into frequency domain → how rapidly does CDF change over its domain?
  \[ FFT(k) = \sum_{n=0}^{N-1} s(n) \exp(-j \cdot 2 \pi \cdot (k - 1) \cdot \frac{n}{N}) \]
  where \( FFT(k) \) is amount of frequency in signal, \( s(n) \) is the CDF, \( n \) is the sample, \( N \) is the number of samples, \( k \) is the frequency

- For a continuous signal, the power spectral density (PSD) computes how “power” is distributed over frequency of the CDF by computing the square of the FFT.
  \[ PSD(k) = |FFT(k)|^2 \]

- Spectral angular mapping (SAM) computes the spectral angle (in radians) between the PSD vector and a matrix of library PSD spectra for the library of radionuclides; the smaller the SAM value the better the agreement:
  \[ \alpha_i = \cos^{-1}\left(\frac{\sum_{k=1}^{N} (PSD(k)_i \cdot PSD_{\text{library}}(k))}{\sqrt{\sum_{k=1}^{N} (PSD(k)_i)^2 \cdot \sum_{k=1}^{N} (PSD_{\text{library}}(k))^2}}\right), \]
  where we compute the spectral angle \( \alpha \) between the PSD of one measurement and the library PSD spectra for any isotope \( i \)

Results and Conclusions
- 100% correct identification with <5000 pulses (corresponding to 3 s dynamic measurement of source moving at 1.2 m/s past pedestrian RPM at 70 cm) on 30 trials per radionuclide for SNM (51 g HEU, 6.6 g WGPu), and a variety of medical and industrial isotopes (see Figure 6)
- Vast improvement over least squares CDF analysis [4]

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Fig. 1. RPMs at Baltimore port. http://www.kentimmerman.com/hkills/portal-monitors.JPG

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Fig. 4. Pulse height distribution (PHD) for long measurement time with pedestrian RPM.

- FFT converts CDF into frequency domain → how rapidly does CDF change over its domain?

Fig. 5. PHD for moving 60Co with pedestrian RPM at JRC Ispra in February 2014.

- Radionuclide ID easy with good statistics (long measurement time)
- In reality, we get this →

Fig. 6. Cumulative distribution functions (CDFs) for library spectra of low energy gamma sources and three dynamic measurements for pedestrian RPM at JRC Ispra in February 2014.

Fig. 7. (a) CDF of dynamic 137Cs measurement with pedestrian RPM; (b) Fast Fourier transform (FFT) of CDF; (c) Power spectral density of FFT.

References

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