Radionuclide Information Barriers using Novel Statistical Approaches

Clair J. Sullivan
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University of Illinois at Urbana-Champaign

How Isotope ID is Currently Done
- Library look up
- Region of interest
- Template matching
- Peak detection

Role of Isotope Identification
- Accurate, automated identifications can allow for the real-time green-light indication
- Can eliminate the need for part or all of the equipment to be viewed
- Can be customized to the specific injury utilization

Our Proposed Research
- Measure the impact of statistical algorithms on isotope detection
- Develop and test algorithms to include a hybrid range of detectors
- Produce highly reliable spectral algorithms
- Quantify and present information barriers related to developed algorithms

Other Potential Contributions by UBC
- Use a standardized resolution tests with the relevant information for effective automated identification
- Test the effectiveness of the proposed algorithms in various real-world scenarios
- Contribute to the development of advanced statistical methods
- CMG-Canada, current, collaboration

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Other Potential Contributions at UIUC
- Thorough information sharing among various nuclear reactor operators
- Enhanced decision-making processes
- Improved computational efficiency
- Increased security and safety measures

Our Proposed Research
- Measurement for impact of omission of empirical functions
- Enhanced radioactivity detection
- Improved statistical methods
- Quantitative assessment of information barriers in developed algorithms

Role of Isotope Identification
- Acceleration of identification processes
- Reduction in analytical time
- Enhanced precision and accuracy

Requirements under the Comprehensive Test Ban Treaty

- CTBT requires signatories to permit on-site inspections (OSIs)
- Measurement of the presence of "relevant" radionuclides
- Prevent access to "non-relevant" nuclides
- Detector selection determined by treaties

*Ideal Solution: Red light/green light*
Role of Isotope Identification

- Accurate, automated identifications can allow for the red light/green light indication
- Can eliminate the need for part or all of the spectrum to be viewed
- Can be customized to the specific treaty obligations
How Isotope ID is Currently Done

- Library look up
- Region of interest
- Template matching
- Peak detection
Detect peaks → Determine centroids → Calculate peak areas → Compare to library → Would I expect to see this peak in my spectrum?

\[
P(\text{iso}|\text{data}) = \frac{P(\text{data}|\text{iso}) P(\text{iso})}{P(\text{data})}
\]

\[
P(\text{data}|\text{iso}) = f_{\text{PFPFAR}}
\]

**152 Eu with 2.1 cm lead shielding**

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<thead>
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<th>Method 2</th>
<th>Method 3</th>
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<td>0.31</td>
<td>0.012</td>
<td>0.15</td>
</tr>
<tr>
<td>123 I</td>
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<td>0.84</td>
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<td>239 Pu</td>
<td>0.0075</td>
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Calculate peak areas
Compare to library
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Our Proposed Research

- Measure the impact of detector response function (i.e. optimal scale curve) on peak quantification
- Expand wavelet and library algorithms to include a broad range of detectors
- Evaluate treaty-specific "relevant" isotopes
- Quantify appropriate information barriers based on developed algorithms
Other Potential Contributions by UIUC

- PI has extensive experience working with the nuclear materials and facility requirements of the DAF and NTS
- PI has direct access to many IAEA inspectors engaged in these measurements today
- Facilities, comms, and accesses at UIUC
- IRRMA-X, Chicago, 2017
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Other Potential Contributions to UBC
- IRP: Information Retrieval Project
- ISC: Information System for Cancer
- IUP: Information System for Physics
- IUC: Information System for Urban

Role of Isotope Identification
- Accurate, automated identifications can allow for the real-time green light indication
- Can eliminate the need for part or all of the machine to be viewed
- Can be transferred to the specific decay obligations

Our Proposed Research
- Measure the impact of individual independent functions (e.g., correction, code, curve)
- Develop empirical and machine algorithms
- Evaluate a broad range of outcomes
- Produce novel machine-learning techniques
- Quantify the potential for error in machine-learning algorithms