A Machine Learning Approach to Identifying Shielded Radioisotopes in Gamma-Ray Spectra
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Goals and Objectives
- Main goal: Develop NaI-based radioisotope identification algorithms that can identify sources in unknown shielding configurations, radiation background fields, and detector calibrations

Introduction
- Machine learning and pattern recognition algorithms might be able to incorporate “intangibles based on experience” (Rawool-Sullivan et al., 2010)
- For low-resolution detectors it may be more beneficial to use algorithms that leverage more abstract features of the spectra, such as the shape of overlapping peaks and the Compton continuum.
- Dense neural networks (DNNs) do not assume nearby channels are related, while convolution neural networks (CNNs) do assume local channels are related.
- Because of this, CNNs may operate better than DNNs for automated gamma-ray spectroscopy.
- Dimension reduction techniques such as principle component analysis (PCA) prevents model overfitting by limiting free parameters

Methodology
- Gamma-ray spectrum templates were simulated using GADRAS
  - 29 isotopes based on the ANSI Standard N42.34-2006
  - Spectra were simulated with linear calibration shifts within ±15 channels for a 661 keV photopeak
  - Shielding materials and thicknesses included are listed below
    - Materials correspond to 20%, 40%, and 60% attenuation for a 662 keV photopeak
- Templates were then used to train a classification DNN, PCA->DNN, and CNN

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness [cm]</th>
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<tbody>
<tr>
<td>Aluminum</td>
<td>2.3 4.1 7.2</td>
</tr>
<tr>
<td>Iron</td>
<td>0.87 1.6 2.8</td>
</tr>
<tr>
<td>Lead</td>
<td>0.42 0.76 1.3</td>
</tr>
</tbody>
</table>

Results
- Weighted F1 scores were compared for simulated spectra
  - F1 score conveys accuracy (1 = perfect, 0 = worst)
  - Spectra were simulated with
    - A different background distribution than the one used in training
    - No calibration shift
    - 0.76 cm lead shielding, where indicated
    - All isotopes in training library

Discussion
- The CNN consistently outperformed both DNNs on simulated shielded spectra (Figs 1-5).
- The DNN and PCA->DNN both generally performed worse with increased integration time
- Between a signal to background ratio of 1.5 and 2.0 performance plateaus

Conclusion
- The CNN’s performance was most promising, consistent with previous findings (Kamuda, Zhao, Huff, 2018)
- Future work
  - Investigate different output structures
    - Unshielded & lightly shielded, medium shielding, heavy shielding
  - Explore unsupervised feature extraction
  - Background subtracting convolutional autoencoder
  - Investigate performance on real gamma-ray spectra

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