SNM Radiation Signature Classification Using Semi-Supervised Machine Learning in Shadow

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Abstract:

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The timely detection of special nuclear material (SNM) transfers is an important monitoring procedure towards nuclear nonproliferation. Further, characterizing anomalous measurements is important for understanding when and why a model or tool raises an alarm. Nuclear monitoring data can be costly to fully characterize and label. Therefore, this work is developing a machine learning model built on semi-supervised learning to utilize both labeled and unlabeled data. Even though the unlabeled data does not provide formally classified instances, it can indicate an underlying distribution or pattern relevant to classification. Radiation measurements from sodium iodide (NaI) detectors are provided by the Multi-Informatics for Nuclear Operations Scenarios (MINOS) venture at Oak Ridge National Laboratory (ORNL) as sample data. Anomalous measurements are identified using a previously developed method of statistical hypothesis testing. After background estimation, an energy dependent spectroscopic analysis can be used to characterize an anomaly based on its radiation signatures. These are applied as features in training a semi-supervised multiclass classification model. Classes are defined by prepared and labeled samples but could be extended to other appropriate SNM scenarios. Using Shadow, a software package developed by researchers at Sandia National Laboratory, consistency regularization is applied using an exponential averaging adversarial training loss algorithm. This can be compared to a baseline supervised model (e.g. logistic regression) to understand the value of included unlabeled data. The study of different semi-supervised models will be continued. This includes more formal quantification of the tradeoffs between labeled and unlabeled data, feature importance, etc. An implementation of this model can be applied to other detection analyses, including data fusion and spatially dependent methods.