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Anomaly Detection in Radioactive Material Transportation Using Isolation Forest

Introduction
Each year, approximately 20 million radioactive material transports occur worldwide. These radioactive materials can pose significant risks to humans and the environment. Despite stringent oversight, the CNS Global Incidents and Trafficking database recorded more than 1,500 incidents involving the transport of radioactive materials reported from 2013 to 2021. This data can be used to develop secure practices for the transport of radioactive materials. Using artificial intelligence, this data can be analyzed to uncover proliferation risks by predicting successful material recovery and detecting anomalous events, aiming to support regulators and law enforcement with proactive analytical tools.

Methodology
This analysis utilized the CNS Global Incidents Database, which contains structured records of nuclear and radiological incidents worldwide. This data records Incident Type, Detection Method, Material Use, Isotope, Country, and other related data. After the data cleaned, Random Forest applied to predict whether lost or stolen material could be recovered. Finally, cross-section validation was used to evaluate the recovery outcome and achieved 87% accuracy and a ROC-AUC of 0.92.
Isolation Forest algorithm applied for anomaly detection to detect anomalies in the transportation process. The result is an "anomaly score" for each incident based on how isolated it was from the overall data pattern; incidents with the highest anomaly scores were flagged for further examination.

Results
The Random Forest classification yielded strong predictive performance (87% accuracy, AUC 0.92), indicating that incident characteristics can reliably predict whether lost nuclear material has been recovered. The most important features are Application, RSG-19 Category, and Incident Type. In particular, incidents involving industrial materials or materials with unknown intended uses are significantly associated with recovery outcomes. These features suggest that incidents related to theft and unclear material characterization need special attention. The unsupervised Isolation Forest model identified 76 anomalous incidents. Specifically, the flagged anomalies included cases of unauthorized possession of radioactive material, lost shipments, and misrouted shipments.

Discussion
This research demonstrates how AI can enhance the security of nuclear material transportation. For example, authorities could use its predictions to identify high-risk thefts or losses with a low likelihood of recovery, thus prioritizing these cases for aggressive investigation and resource allocation. Anomaly detection could be used as an automated alert system for anomaly response, flagging irregular incidents that might otherwise be missed in routine reporting. Such early detection of anomalies allows for faster incident response and corrective action, potentially mitigating security breaches.

Country or International Organization

Instructions

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