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Application of Artificial Intelligence in Nuclear Forensics: Findings of a Dedicated Workshop

Introduction
Whenever nuclear or other radioactive material is found out of regulatory control, the investigating authority needs to identify the radiological hazard associated with the material, the potential origin of the material and the route it has taken after regulatory control was lost. In order to answer these questions, (samples of) the seized material may be subject to nuclear forensic analysis. Characteristic parameters, colloquially referred to as "nuclear forensic signatures", are measured; such as the isotopic composition, elemental composition, molecular structure, morphology, decay products or trace elements.
Data interpretation is typically achieved by comparative evaluation (e.g. classification) using data obtained from samples of known processing history and origin (e.g. from national nuclear forensic library). Statistical techniques and subject matter expertise are traditionally used to infer processing history and potential origin of the material.
The application of Artificial Intelligence (AI) tools, however, may offer new avenues in data evaluation in nuclear forensics.

Present Work
The paper describes the outcomeof a dedicated workshop, which was co-organized by the European Commission Joint Research Centre (JRC) and the Norwegian University of Life Sciences (NMBU). The workshop brought together experts from two different communities, which haven't been exposed, to each other very much: nuclear forensic scientists and experts in the field of Artificial Intelligence. The event was sponsored through the JRC's Enlargement and Integration program and gathered relevant experts from EU Member States, from Norway, Ukraine, Turkey and Japan, affiliated with universities or research organizations. The workshop aimed at transferring knowledge from fields such as medical image analysis or food analysis in particular with a view to authentication, compliance verification and classification.
The key challenges with data in nuclear forensics arise from small data-sets, inhomogeneous (aggregated) data, incomplete data-sets, sensitivity/confidentiality of data, transparency of conclusions and confidence in conclusions. The workshop addressed these challenges by presenting and examining areas such as explainable AI, feature selection, predictive AI or multi-block data. Examples were provided where AI methodologies such as machine learning or deep learning are applied for analyzing data originating from simple measurements (isotope ratios, concentrations), from recording spectra (infra-red, Raman, gamma ray), from images (photography, optical microscopy, electron microscopy) or from complex analytical techniques (hyperspectral images, tomography).
Through the round table discussion a clearer picture of a path forward could be established, which was captured in five recommendations:
• Promote the use of distributed learning models to enable handling of sensitive data
• Establish an interface between subject matter experts and feature/parameter selection (by AI) to increase transparency of conclusions
• Develop multi-block data analysis for comprehensive description of nuclear material using information from various measurement techniques
• Examine the application of transfer learning
• Investigate the usefulness of synthetic data for training, re-training and validating models

The findings of the workshop will inspire the work program of the nuclear forensic community and serve as basis for multi-lateral cooperation. As the discussions have shown, the area of nuclear forensics can significantly benefit from applying AI methodologies.

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