Comparison of machine learning models for the sck cen detection of partial defects in spent nuclear fuel

Methods

Cd sheet (optional)

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Introduction

One of the tasks of the International Atomic Energy Agency (IAEA) is to detect the diversion of nuclear material from peaceful activities to other purposes such as the development of nuclear explosive devices.

The safeguards inspections are carried out in the Member States that ratified the Non-Proliferation Treaty (NPT) to verify the nuclear material inventory declared by each country.



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European Commission



(a) Fork

Stainless steel box

Machine learning approaches

(a) k-Nearest Neighbors



The nuclear material (i.e. ²³⁵U, Pu) contained in spent fuel represents the majority of the material verified during the safeguards inspections, and the replacement of spent fuel pins from an assembly is one of the possible scenarios to divert nuclear material.

According to the safeguards terminology, the replacement of several fuel pins from a fuel assembly is called partial defect.

Objectives

Objective 1: detect the partial defects from a fuel assembly and classify the fuel assemblies according to the percentage of replaced pins.

Objective 2: compare three passive Non-Destructive Assay (NDA) techniques and two machine learning approaches in terms of capability to detect the partial defects.



k-Nearest Neighbors approach

- > Largest accuracy values with number of neighbors between 6 and 10
- \succ Neutron features give largest accuracy values with Fork detector
- \succ P and FA features give largest accuracy values with SINRD and PDET instruments



Decision tree approach

- \succ Increase in accuracy values with the maximum number of splits
- \succ Similar results for all features of the Fork detector
- \succ P and FA features give largest accuracy values with SINRD and PDET instruments



Comparison of NDA techniques

- Accuracy values for the Fork detector are in general lower than for the SINRD and PDET
- \succ In case of kNN models, accuracy values for PDET are 20-30% larger than for SINRD
- Similar results between PDET and SINRD were obtained using the decision tree approach
- kNN models using the P and FA feature can reach complete correct classification



Conclusio

- > The accuracies values obtained for the decision tree models increase by increasing the maximum number of splits in the decision tree, whereas the accuracies for the kNN models decrease by increasing the number of neighbors.
- \geq In general, the accuracies for decision tree models are lower than the values with the corresponding model using the kNN approach.
- > The model accuracies using the Fork detector are lower than in the cases of SINRD and PDET. In the case of kNN models the accuracies calculated for PDET are in general 20-30% higher than for SINRD. In the case of decision tree models no significant differences were observed on the model accuracies calculated for SINRD. and PDET, with largest values obtained using the P or FA features.
- \geq Complete correct classification was achieved with SINRD and PDET using the detector response from the ionization chambers.

