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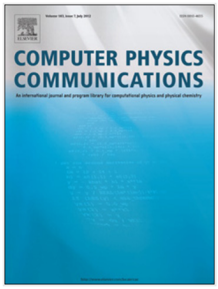

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Dynamic Analysis Environment for Nuclear Forensic Analyses

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Abstract

A Dynamic Analysis Environment (DAE) software package is introduced to facilitate group inclusion/exclusion method testing, evaluation and comparison for pre-detonation nuclear forensics applications. Employing DAE, the multivariate signatures of a questioned material can be compared to the signatures for different, known groups, enabling the linking of the questioned material to its potential process, location, or fabrication facility. Advantages of using DAE for group inclusion/exclusion include built-in query tools for retrieving data of interest from a database, the recording and documentation of all analysis steps, a clear visualization of the analysis steps intelligible to a non-expert, and the ability to integrate analysis tools developed in different programming languages. Two group inclusion/exclusion methods are implemented in DAE: principal component analysis, a parametric feature extraction method, and k nearest neighbors, a nonparametric pattern recognition method. Spent Fuel Isotopic Composition (SFCOMPO), an open source international database of isotopic compositions for spent nuclear fuels (SNF) from 14 reactors, is used to construct PCA and KNN models for known reactor groups, and 20 simulated SNF samples are utilized in evaluating the performance of these group inclusion/exclusion models. For all 20 simulated samples, PCA in conjunction with the Q statistic correctly excludes a large percentage of reactor groups and correctly includes the true reactor of origination. Employing KNN, 14 of the 20 simulated samples are classified to their true reactor of origination.

Keywords: nuclear forensics, principal component analysis, k nearest neighbors algorithm

1. Introduction

Nuclear forensics is a branch of science in which questioned nuclear materials are characterized with regard to their isotopic and elemental composition, age, physical state, history, and provenance [1]. The characterization and interpretation of a questioned nuclear material may require the integration of information from a wide array of sources, including visual inspection and laboratory analyses of the material, computer modeling, and a comparison of the features or signatures of the questioned nuclear material with those of known materials [2].

Nuclear forensics data sets or libraries of known nuclear materials have been developed against which to compare questioned materials. These libraries, in conjunction with multivariate pattern recognition algorithms, enable the linking of questioned materials to their potential processes, location, or fabrication facility [3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. This linking procedure is performed by systematically comparing the multivariate features/signatures (e.g., isotopic or trace element measurements) for a questioned nuclear material to the signatures for materials originating from different, known groups or classes (e.g., specific nuclear reactors, processes, or locations), enabling both group exclusion and inclusion. Exclusion refers to the process of eliminating the possibility that a questioned material originated from a particular group, based on a rigorous statistical comparison of the signatures for the questioned material and known materials

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