Information Visualization of Nuclear Decay Chain Libraries

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ABSTRACT

This poster presents multiple information visualization techniques for scientific visualization of the nuclear isotope decay process, including (but not limited to) circle packing and directed graphs. The practical goal of this visualization process is to support nuclear forensics, the identification of the origin of intercepted smuggled nuclear materials.

Categories and Subject Descriptors

[**Visualization techniques**]: Visualization; [**Visualization application domains**]: Visualization—*Information visualization*; [**Modeling and simulation**]: Simulation types and techniques—*Scientific visualization*

Keywords

nuclear forensics, nuclear decay, visualization, circle packing, directed graph

1. INTRODUCTION

In the "Recasting Nuclear Forensics Discovery as a Digital Library Problem" project, we are applying a variety of Digital Library (DL) methods to support the identification, localization and detection of illicit nuclear materials. One issue that has arisen is how to present scientific measurements and findings in a clear and cogent manner. Information visualization gives us a method to present this complicated information when it is designed with techniques that optimize understanding of the analysis and support the requirement that it be defensible in a courtroom. Visualization is complementary to underlying DL information structures which support implementation of nuclear forensics discovery[3].

Nuclear material data is a digitized record of assays for component isotopes[1] and elements. Search of this data is complicated by the fact that radioactive atoms decay or morph constantly into atoms of different isotopes as the material decays. This morphing activity creates a new component for the same material. Therefore matching the original record is impossible against itself or any other nuclear material data unless the decay activity is built into the search algorithm. A nuclear material is composed of multiple radioactive isotopes. Therefore the decay visualization design must handle multiple events which can be confusing and difficult to comprehend unless the information is presented for optimal understanding.

2. VISUALIZATION DESIGN MODES

Our poster presents multiple approaches to the visualization of the nuclear decay process and its application to nuclear materials matching. We will also describe the entire digital library structure that we are developing for nuclear forensics discovery.

2.1 Circle Packing

Nuclear material isotope composition can be visualized using circle packing, a geometry where enclosure diagrams use containment to represent the hierarchy. In a Euclidean plane, the circle packing mechanism configures circles with a prescribed pattern of tangencies, yielding no two overlap circles in a contained boundary with most of the circles mutually tangent. The circle packing theorem is founded upon a rich body of classical geometries and we draw inspiration from Wang[5] and Heer[2] where circle packing was used to illustrate large datasets with hierarchies.

We visualize isotope composition of measured nuclear material assay taken from the Los Alamos National Laboratory (LANL)[1], which undertakes classified work towards the design of nuclear weapons and together with Lawrence Livermore National Laboratory (LLNL) are the two major laboratories doing such security nuclear forensics work to enhance the nation's defense. The nuclear material sample is analyzed by dividing it into aliquots which are subjected to iso-

[1]The data demonstration items are unclassified weapons grade nuclear material samples from the Plutonium Metal Standards Exchange Program at the Laboratory Chemistry and Materials Science Division, Los Alamos National Laboratory.

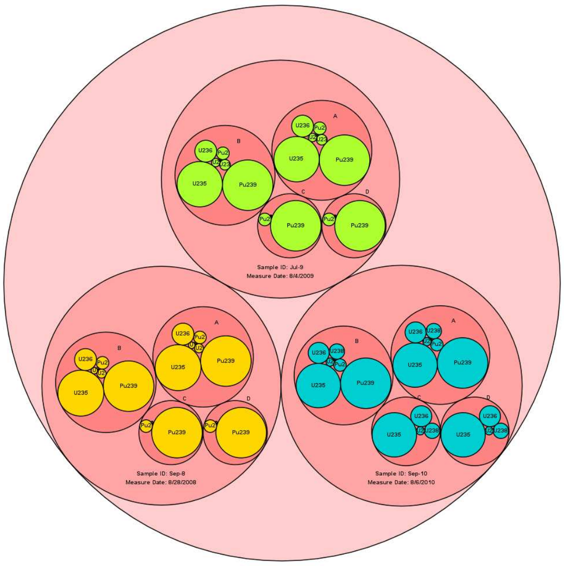

Figure 1: Example of circle packing visualization of three samples measured in LANL with their isotope composition.

topic specific tests. In the example, three samples measured on different dates are presented with unit circles. Within each circle are the sample's aliquots and various isotopes observed are displayed inside the aliquot circles. The area of the isotope circle is determined by the numerical value of weight percentage of that isotope within its element. For instance, aliquot A from sample ID Sep-10 consists of U-234 (2.5% U), U-235 (73% U), U-236 (16% U), U-238 (8.7% U), Pu-239 (94% Pu) and Pu-240 (5.8% Pu). The area of the corresponding circles is proportional to the element percentages. Accordingly, isotope circle with larger area suggests that the isotope is more abundant within the element.

2.2 Directed Graph

The decay events of a nuclear material can also be modeled as a directed graph where isotopes are represented by nodes and decay events from parent to daughter are represented by directed arcs. Modeling the decay activity as a directed graph allows for visualization of the process but also produces new information possible with graph analysis methods.

The following directed-graph visualization example shows the result of decay-chain generation using data from the Nuclear Wallet Cards database[4], which catalogues properties for ground and isomeric states of all known nuclides. The graph displays a composite of nuclear decay chains with root parents being the various isotopic assays recorded in the sample nuclear material. Those isotopes are Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, U-234, U-235, U-236, and U-238. Types of radioactive decay and isotope half-lives are highlighted on the graph. The directed-graph of networked decaying isotopes is built to illustrate the decay network until the isotopes reach a stable state at which they stop decaying.

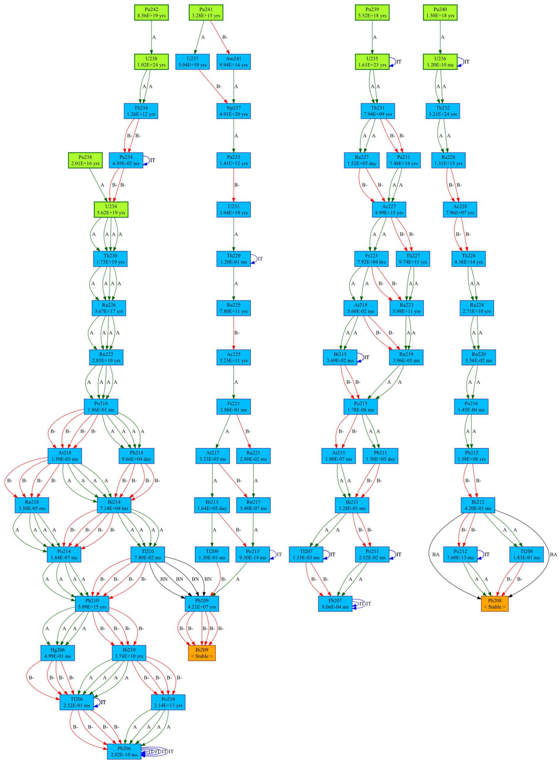

Figure 2: Example of directed-graph visualization of isotope assays of LANL measured nuclear material (Aliquot A, Sample ID: Sep-10).

3. ACKNOWLEDGMENTS

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