Chapter 46
Assessment of Fuzzy Logic Radioisotopic Pattern Identifier on Gamma-Ray Signals with Application to Security

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ABSTRACT

Analysis of acquired nuclear detector gamma-ray signals for recognition of present radioisotopic signatures is crucial to national security and security applications. Identification algorithms must be accurate and rapid. Artificial intelligence is a scientific field with a variety of tools suitable to implement automated processing of nuclear signals. The use of low resolution portable detectors to measure gamma-ray signals has found a wide use in security and safeguards applications. In this paper, the fuzzy logic based analysis methodology that has been previously developed is applied and assessed on a variety of nuclear signals obtained with a low resolution scintillation detector, and more particularly a sodium iodide (NaI) detector. Various types of fuzzy membership functions are employed and their performance is assessed with regard to the number of positive detections, misses, and false alarms. Furthermore, recorded results from the set of low resolution gamma ray signals are used to estimate the detection sensitivity for each membership function. Results demonstrate the overall effectiveness of the fuzzy logic based identifier, and consist of the main course for the assessment of each membership function. Furthermore, comparison of results designates the triangular membership function as the best membership shape for this type of detector signals.

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INTRODUCTION

The increasing concern over terrorist attacks with nuclear weapons in the last decade necessitated the development of new countermeasures for enhancing national security, safeguards and public safety. Detection and identification of illicit materials potentially convertible into nuclear weaponry, known as special nuclear material (SNM), is one of the last barriers against nuclear terrorism. The search for hidden SNM focuses on two main points: in scanning cargo containers in a country's entry ports and in urban searches with mobile detectors.

One example of nuclear signals is the gamma spectra. Measurement of gamma radiation is one of the most common techniques for detection of threats. Gamma signals are processed in order to extract a nuclide's gamma signature from the overall signal. In general, a gamma detector provides a signal which is the aggregation of nuclides' signatures and ambient background radiation.

Analysis of measured signals is a significant aspect of the overall detection process. Its goal is to recognize the signatures of interest and subsequently identify the respective material. Efficient analysis requires a high positive detection and a low false alarm rate. Computationally, the efficiency of the analysis must be able to handle the large volume of incoming data, which requires fast processing and decision-making. Clearly, every developed algorithm aims to maximize efficiency and minimize processing time.

Nuclear spectrum processing is an active research area and a significant amount of methodologies have been proposed. Artificial intelligence tools have found wide use in analyzing detector signals and recognizing hazardous materials. Neural networks have been used for analysis of gamma spectra as presented for germanium detectors by Yoshida et al. (2003) and for scintillator detectors by Kucuk & Kucuk (2003). Furthermore, the use of neural networks for real time analysis of gamma-ray signals and subsequent identification of radioactive isotopes is introduced in (Keller & Kouzes, 1993), while a multi-level perceptron was used for improving signal-to-noise-ratio in measurements as presented in (Yearworth & Miller, 1993). Genetic algorithms were also applied for detector signal analysis as shown in (Carlevaro et al. 2008) with the drawback that those methods are seemingly effective only for simple spectra. A methodology integrating evolutionary computation and fuzzy logic was introduced in (Huang et al. 2006), while expertise *if-then* rules were introduced in (Lehner at al. 2003) and in (Alamaniotis et al. 2009) for intelligent processing for gamma-ray signals. Other methodologies based on fuzzy logic approaches were proposed in (Murray et al. 2000) for CZT signals, and in (Alamaniotis et al. 2011) for Nuclear Resonance Fluorescence (NRF). The intelligent technique of LG-graphs was applied on radiation signals by Bourbakis et al. (2008) and by Pantelopoulos et al. (2009).

In a previous paper (Alamaniotis et al. 2011), the authors have applied their developed smart algorithm for processing of signals acquired with a nuclear detector. The underlying principles of intelligent information processing of their algorithm are based on the well-developed tools of fuzzy logic (FL) (Tsoukalas & Uhrig, 1997). The FL tools are used for maxima identification as well for making inferences over the sources identified in a signal. The advantage of FL Radiation Isotope Identifier (RIID) algorithm is that it does not require training and supports automated and expedient analysis of spectral content without regard to the complexity of the measured signal. At the same time, uncertainty and ambiguity over detected results is handled with the computation of decision certainty factors.

This paper is organized as follows: In the next two sections, the fundamentals aspects of nuclear detection applications are introduced, and the fuzzy logic analysis algorithm is briefly presented. Following those two section, there is a section in which the membership functions of interest are shown and the results of application of the fuzzy logic tools to simulated gamma ray