ABSTRACT

Fast processing of consecutive measurements and accurate detection of abrupt changes is of primary importance for online monitoring of radiation. In this paper, a hybrid anticipatory system is discussed together with its application to real time radiation monitoring. The system utilizes the synergism of an artificial neural network (ANN) with support vector machines (SVM) to tackle the problem of anticipating the measurements for an ahead-in-time horizon. The system employs an ensemble of support vector regressors (SVRs) whose predictions constitute the input values to a neural network. Therefore, it is the neural network that provides the final predictions over the designated time horizon. The neuro-SVM predictions are divided by the respective observed values and compared with a predetermined threshold where an abrupt change is identified if the ratio exceeds the threshold value. The proposed anticipatory system is compared with the naïve prediction approach as well as the independent support vector regressors. Results clearly demonstrate that the neuro-SVM outperforms the naïve predictor and the individual SVRs in the majority of the cases regarding prediction accuracy and rate of abrupt change detection.

Keywords: Abrupt Change Detection, Artificial Neural Network (ANN), Neural Network, Radiation Monitoring, Support Vector Regressors (SVRs)

INTRODUCTION

In nuclear engineering, processing of radiation signals is of great significance for monitoring of radioactive sources and detecting abrupt changes in consecutive measurements. Radiation measurement systems display the number of electric pulses (i.e. counts) produced by the interaction of a specific type of particles, such as photons, neutrons, cosmic rays or any other, in the detector’s sensing element (Tsoulfanidis & Landsberger, 2010) for a given time interval.

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So, it is common for registered counts to result from radioactive sources and naturally occurring radioactive materials (Ely et al., 2003) in close proximity from the sensor location. In a static environment, a radiation measurement system displays a series of counts, whose gross number fluctuates around a value. However, in reality the majority of environments are dynamic and the radiation gross number exhibits several abrupt changes or transitions. Therefore, long term recording of radiation measurements for a specific location allows ahead-of-time estimation of the count number “be reported” by a radiation sensor. As a result the crucial step in monitoring is finding an abrupt change as soon as possible by recognizing unusual measurements, i.e. radiation recordings that do not match the expectations fostered by previous observations.

Towards that end, artificial intelligence (Russell & Norvig, 2002) has a great potential with respect to creating intermediate infrastructures for developing and/or combining various monitoring methodologies. Fusion and processing of multi-source data, can be combined with intelligent tools to achieve significant improvement of surveillance parameters. More specifically, automated implementation of the associated processes can decrease the required measurement time, while intelligent processing of the obtained signals can shorten abrupt change detection time.

Several methods for radiation monitoring and subsequent abrupt change detection are already in use and even more are and will be proposed (Fagan et al., 2012). The efficiency of each technique is based on a set of unique characteristics, appropriate for either count estimation or measurement analysis. Particularly, Stephens and Peurrung (2004) studied the use of multiple sensors and information fusion in monitoring radioactive sources. Apostolopoulos (2008) applied tools from statistical signal processing for radiation monitoring and detecting abrupt changes in measurements. Pfund et al. (2010) proposed an anomaly detection algorithm based on weighted spectral comparison ratios, while Tardiff et al. (2006) proposed a methodology adopting principal component analysis for anomaly identification. Principal component analysis was also employed for data analysis in portal monitors by Runkle et al. (2006). The sequential probability ratio test (SPRT) has been extensively applied in radiation monitoring since it was part of several methodologies such as those proposed by Fehlau (1993), Jarman et al. (2004), and Luo et al. (2010). Adoption of Kalman filter for tracking background measurements was proposed by Jarman et al. (2008), and a matched filter based approach for vehicle portal monitors was introduced by Runkle et al. (2005). Further, the use of wavelets in detecting radiation anomalies was proposed by Ominoamou et al. (2009).

Although these methods have been traditionally used for stand-alone monitoring, the belief that has been evolving in the research community is that combination of techniques is likely to increase inspection efficiency. Toward that end, researchers have focused on developing methodologies for bringing developed and proposed technologies together (Tsoukalas, 1997; Ikonomopoulos et al., 1993). The ultimate goal is to build hybrid systems with enhanced accuracy (i.e., the most optimal proportion of positive and false alarms) and increased detection speed.

In this paper, a smart anticipatory system for gamma radiation monitoring is proposed. The aim of this system is to provide an intelligent frame for integration of ahead-of-time measurement prediction with fast abrupt change detection processes. The proposed anticipatory system is based on independent support vector regressors (Bishop, 2006) that constitute the inputs of an artificial neural network (Tsoukalas & Uhrig, 1997). The goal of the proposed system is to predict future measurements, and to compare them with real observations and hence to infer whether there is an abrupt change or not. Thus, the final output of the proposed system is relying on predictions made by the artificial neural network, which is trained on recent past recordings. The system is able to
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