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Analysis of Integrated Video and Radiation Data

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ABSTRACT

We have developed prototype software for a facility-monitoring application that will detect anomalous activity in a nuclear facility. The software, which forms the basis of a simple model, automatically reviews and analyzes integrated safeguards data from continuous unattended monitoring systems. This technology, based on pattern recognition by neural networks, provides significant capability to analyze complex data and has the ability to learn and adapt to changing situations. It is well suited for large automated facilities, reactors, spent-fuel storage facilities, reprocessing plants, and nuclear material storage vaults.

I. INTRODUCTION

Facility monitoring for safeguards requires the use of multiple sensors, including cameras and radiation sensors. The time interval for data collection must be small enough to avoid missing a critical event in the area being monitored. In some cases, 1- to 2-s time intervals are required to provide the required temporal resolution. As the number of sensors increases and the time interval between data points decreases, much data accumulates and new computer-based techniques are required to evaluate the information. We are developing new technology to automate the integration of video images with multiple sensors in large data arrays.

Because of the need to store large quantities of data in an unattended mode, the data must be compressed and reduced when collected and stored so that the storage media do not fill up. Another fundamental problem is the integration of the combined data because the two methods operate in different dimensions. The approach we have taken in handling the video data addresses both of these issues. The containment/surveillance (C/S) video data is spatial in nature, whereas the nondestructive assay (NDA) sensors provide data on radiation levels versus time. Changes in the scene are quantified using a metric, a pixel difference, that provides motion levels versus time in addition to the spatially oriented video data. The pixel difference is calculated as the number of pixels that differ between the current scene and some baseline picture taken when there was no activity in the area. In our approach, the video component becomes another detection element as well as a traditional recording instrument. When the present pixel difference threshold is exceeded, the entire image is stored. We call this approach to data fusion the Video Time Radiation Analysis Program (VTRAP).

This paper will describe the VTRAP technology and present data from our laboratory test facility that has been developed to test the concepts.

A. Prototype System Radiation Sensors

To develop and evaluate the VTRAP concept, we have established a test bed in a controlled radiation laboratory at the Los Alamos
National Laboratory. The equipment includes a nuclear material vault, a radioactive source shield, two neutron-slab totals detectors, a neutron coincidence detector (HLNC-II),6 and a digital video camera. The location of the equipment is shown in Fig. 1.

A typical neutron sensor consists of a $^3$He tube in a polyethylene moderator, a PDT-110A preamplifier, and a LON$^5$ module for connection to the data collection network. All of the neutron sensors are controlled by a single portable shift register$^4$ (PSR) unit. The PSR unit supplies the high-voltage bias, preamplifier power, and coincidence logic and collects data and transmits it to the collect computer. Each slab totals detector consists of six (1 in. by 12 in.) $^3$He tubes placed into a moderating slab of high-density polyethylene. The well detector is an HLNCC-II NDA counter. Data is collected from these counters using the PSR, which is controlled by a Sun workstation.

The three neutron detectors used in our prototype are currently controlled by data acquisition computer code newly developed at Los Alamos National Laboratory. This program communicates with the shift registers and tallies the neutron counting data from each timing interval. This code also provides the ability to perform NDA of samples placed into the well counter.

B. Video System

The present video system$^3$ uses image processing technology to acquire “basis” information about the area being monitored; from this basis, image processing methods are applied to detect changes, or events, in the monitored area. The image processing subsystem is implemented around a SPARC architecture computer system equipped with 1-4 processors, up to 512 MB of internal RAM, up to 4 GB of data storage, and up to 24 camera ports.

In the current VTRAP prototype, up to four cameras are set up by an authorized system operator using the point and click features of the video graphical user interface. Cameras are set up while the monitored area is at “steady state,” i.e., no humans are present, the lights are on, and all security

![Diagram of the radiation laboratory](image)

**Fig. 1.** Diagram of the radiation laboratory for testing the facility monitoring sensors including the video camera, two neutron totals counters (#1 and #2 neutron coincidence counter, well detector), and a shield or vault for storing radioactive sources. Some possible movements of material are indicated by arrows.
doors are closed. On start-up, basis information is acquired for each camera's field of view. Thereafter, the area is continuously monitored in real-time, with 1 s required for processing each camera's input. In this configuration, a room covered by four cameras is fully monitored in about 3 s.

When a change is detected, an image showing that change is stored and labeled by time, date, and camera number. Data collected during preliminary testing shows that a typical change detection consists of one image detecting the opening of the vault door and several images showing one or two personnel moving through the area. If material is added to the vault inventory, the new materials are shown as the personnel place them in the vault. When the personnel have left the vault, new basis images are automatically acquired, and the previously detected difference images are stored for review by the operator. Common events that are detected include entry to the area by personnel for maintenance, materials addition or removal, and inventory. From the stored images, the software and the inspector can review the changes that occurred in the vault for their safeguards relevance.

C. Pattern Recognition Software

Introduction. This software performs a review function that is useful to an inspector or anyone else interested in examining plant data for possible anomalous activity. It runs off-line, that is, it runs on data that was previously collected and stored on disk.

Several steps must be carried out to prepare the software to recognize an event pattern. On a set of historical data collected for training we must

- Identify each "event,"
- Extract features in the data,
- Use the features to generate a training set for the neural network, and
- Train the network to identify anomalies.

Once the network is trained, the steps to be taken in identifying an anomalous event are similar. Using data recently collected, and in which the inspector is interested, one must

- Identify each "event,"
- Extract features in the data,
- Use the features to generate a "recall" data set, and
- Process the recall data set with the neural network, which locates anomalies.

The following is a brief description of each of the above steps.

Event Identification. Because the data is collected continually, some method for identifying activity within the room has to be devised. Once an "event" is identified, then the anomaly detection network can be used to determine whether the event is normal or anomalous. In designing an event identification mechanism, we assume that any activity "of interest" within the room would be indicated by an increased neutron count rate within the wall neutron detector. In other words, unless nuclear material is removed from the safe, no neutron data is recorded in the wall detector and, hence, the activity is not of interest. In a production system, this may not be a valid assumption. We may want to key on a video event or some other data point.

The event identification mechanism devised is based on a threshold that is presently calculated using the running average of the background in the wall detector. When the neutron count level in the wall detector exceeds the threshold, the presence of an "event" is indicated.
**Feature Extraction.** Using the collected set of integrated data and the event identification mechanism just described, we can extract events of interest from the data set. A number of features that characterize these events are then extracted to train and test the anomaly detection network. The features are extracted using the following scheme. When a neutron event in the wall detector is identified, the time of that event is recorded. Then, from the data recorded at this time, 15 features are calculated, such as count rates from all detectors, pre- and post-average, and maximum value from neutron counters. These features are calculated for each of the events (normal and anomalous) identified in the acquired data. The features are then incorporated into training and test data sets that are used to train the anomaly detection neural network.

**Neural Network Training and Recall Steps.** A neural network is an iterative numerical technique that facilitates the solution of a number of different types of problems including pattern matching and data categorizing. Neural networks are so named because of their similarity to actual biological neurons and their connections. They have attracted attention recently and, now that hardware implementations are becoming available, their appeal for use in data acquisition and control systems is increasing. Their usefulness in a variety of safeguards systems has already been shown.¹

The neural network that we use to model the material movements and recognize patterns is a simple back-propagation network with 15 inputs and 3 outputs. The 15 inputs correspond to the 15 features described above, and the 3 outputs correspond to the 3 types of material movements: A, B, and C. The collected data is divided into two sets: a training set and a test set. The training and test sets both consisted of 95 records.

During the recall step, data that the network has never seen is presented for recognition. The network categorizes the data as either normal or anomalous based on the 15 features mentioned above. The quality of the categorization depends heavily on the quality of the training.

In a production environment, a network would have to be built that could discriminate between normal and abnormal, rather than try to categorize each event individually. One cannot hope to anticipate every different type of event and build each of them into the network.

**II. EXPERIMENTAL DATA AND RESULTS**

We have defined procedures for data collection to simulate both “normal” and “abnormal” activity in a facility. The normal activity included moving a small radiation source (²⁵²Cf) from the neutron shield, past detector #1 on the wall, and into the coincidence counter for about a 1-min. count. This movement was then reversed back into the shield. This results in data shown in Fig. 2 for a type “A” event. A type “B” event is to remove the material from its shield and exit the back door. For type “C” movements, we walk to the front of the room and stand under the camera. This is represented by the data in Fig. 3. Two new types of movements have been identified, and we have collected data for them as well, but have not included them in our study. One of these is “D,” in which we measure the material in the coincidence counter as in “A” and then walk to the front of the room and stand under the camera. The other is “E,” in which we measure the material in the coincidence counter as in “A” and then exit the back door.

Each event was repeated a number of times to produce a data set used to train and test the neural network. Examples of data collected and analyzed are shown in Figs. 2 and 3.

We have built and tested neural network software to automatically review and analyze this data collected in a continuous and
unattended mode. Using this technique, we are able to distinguish normal material movements from abnormal activity. Additional code has been written to provide an event summary, indicating when events occurred, their approximate duration, and data gaps that might indicate diversionary activity.

III. CONCLUSIONS

We have developed and tested transformation algorithms for VTRAP data that integrate temporal heterogeneous data into a consistent homogeneous data set for neural network analysis. Transformation algorithms have been applied to two-dimensional digital video images (movement) and radiation signals (nuclear material) to provide time-based data for automated analysis on movements of personnel and nuclear materials. This analysis could be extended to evaluate the system’s ability to recognize personnel and movement and to identify radiation and provide information on nuclear material types, isotopics, and mass. Continuing developments will allow evaluation and integration of additional sensor systems, such as smart portal monitors that provide signatures, face recognition, and fingerprints in addition to power-line monitors that monitor plant operations.

We are enhancing the overall effectiveness of safeguards evaluations through online integration of digital video data, radiation monitoring, and other sensor data. Neural-network pattern-recognition analysis of these integrated safeguards data sets facilitates evaluation by showing trends, discovering anomalies, and highlighting specific activities for detailed review by inspectors.
IV. REFERENCES


