Intelligent Monitoring and Analysis for Safeguards Applications

Kirsten F. Laurin-Kovitz* and Thomas F. Ewing
Argonne National Laboratory

Mailing Address: Argonne National Laboratory,
9700 S, Cass Ave., Bldg. 315, Argonne, IL 60439 USA
klaurinkovitz@anl.gov

ABSTRACT

Application of intelligent systems for safeguards addresses emerging domestic and international needs for automated monitoring and analysis of safeguards-related data. The Intelligent Monitoring System for Safeguards Applications project is focussed on developing advanced software components for the synthesis and analysis of nuclear material safeguards related data to maximize nuclear material safety and security while reducing operational costs. Information is collected from a variety of sources such as nuclear material monitoring and surveillance sensors, measurement devices, and records. Knowledge-based and statistical computational methods are used to integrate and analyze this diverse data to provide comprehensive monitoring and analysis that enhances the detection of sensor degradation or failure, material instability, and material tampering or diversion.

A prototype intelligent monitoring system has been created which features an Expert System analysis module with a knowledge base of heuristics developed from interviews with MC&A and security professionals. The Expert System performs analysis of data and sequences of events to detect subtle inconsistencies or abnormal operating patterns and provides extended diagnostic capabilities. The system was developed using simulated sensor data that represent a variety of safeguards scenarios identified by safeguards experts.

INTRODUCTION

Nuclear materials are being stored in a variety of facilities within the United States and abroad. The United States has committed to help secure nuclear materials in foreign nations, most notably the countries that comprise the Former Soviet Union. In a speech before the IAEA Symposium on International Safeguards in Vienna in October 1997, IAEA Deputy General Hans Blix stated that the current methods of verification, relying on physical access by inspectors, are inadequate and labor intensive. In 1998, the International Atomic Energy Agency (IAEA) performed over 2500 inspections and handled 1 million data records as part of its safeguards activities. As the number of inspectors and data records grows, the task of safeguarding nuclear material around the world becomes progressively more difficult and costly. Blix believes that in the future a greater reliance on automated techniques for remote monitoring and evaluation/review of collected data will be essential. In a speech to the National Press Club, Former Secretary of Energy Bill Richardson stated that “Detecting nuclear weapons (and

*Work supported by the U.S. Department of Energy under contract No. W-31-109-ENG-38.

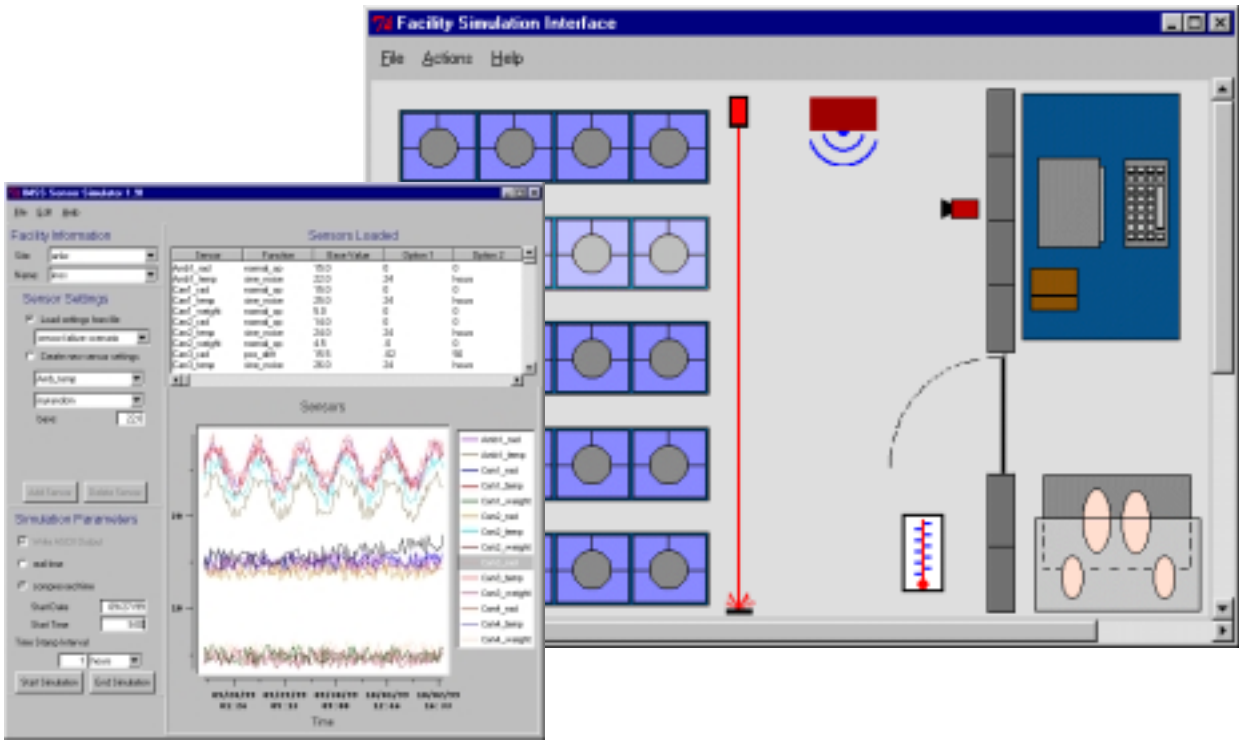
materials) requires not only better technology, but also better ways of interpreting the information that is gathered".

This paper discusses the design and testing of a prototype intelligent monitoring system for safeguards applications that provides support to human safeguards professionals through automated monitoring and data analysis. Advanced software components for the synthesis and analysis of nuclear material safeguards related data are described.

SYSTEM DESCRIPTION

The prototype intelligent monitoring system, which was developed at Argonne National Laboratory, is comprised of several advanced software modules. Together these modules provide extended diagnostic information to assist human operators in evaluating a plethora of safeguards-related data.

The system was developed using simulated sensor data that represent a variety of safeguards scenarios identified by safeguards experts. Software modules that generate sensor and security device data are contained within a Facility Simulator and are shown in Figure 1. The Facility Simulator can be configured to replicate pre-defined scenarios such as sensor failure/degradation, material instability and material diversion, or can be used interactively to modify and trigger sensor and security device settings. This tool can be used for testing the response of the prototype to new, dynamically changing information.



The data from the simulated sensors is conditioned by Data Reduction and Abstraction modules. These modules analyze the data to establish the sensor "states" and reduce the data to the form needed by the expert system module.

The main component of the intelligent monitoring system is an Expert System analysis module. The Expert System uses a knowledge base of heuristics acquired through interviews with MC&A and security professionals. This rulebase incorporates information from material attribute sensors and vault security devices. The Expert System processes the states of all sensors as established by the Data Reduction and Abstraction modules and correlates the data with sequences of events, searching for subtle inconsistencies or abnormalities, and displays a diagnostic message. Information can be integrated from a variety of sources such as sensor time histories, access logs, material control and accounting (MC&A) data (inventory, transaction history) and video images to provide comprehensive monitoring of sensor health, material integrity and material safeguards/security.

The user can confirm the Expert System-derived conclusions with Verification modules incorporated within the prototype system. Software tools allow users to examine plots of the relevant data using the graphing tool or review historical averages of sensor information with the table tool. A 3D Map displays the location of alarm events within the facility and provides links to the verification tools.

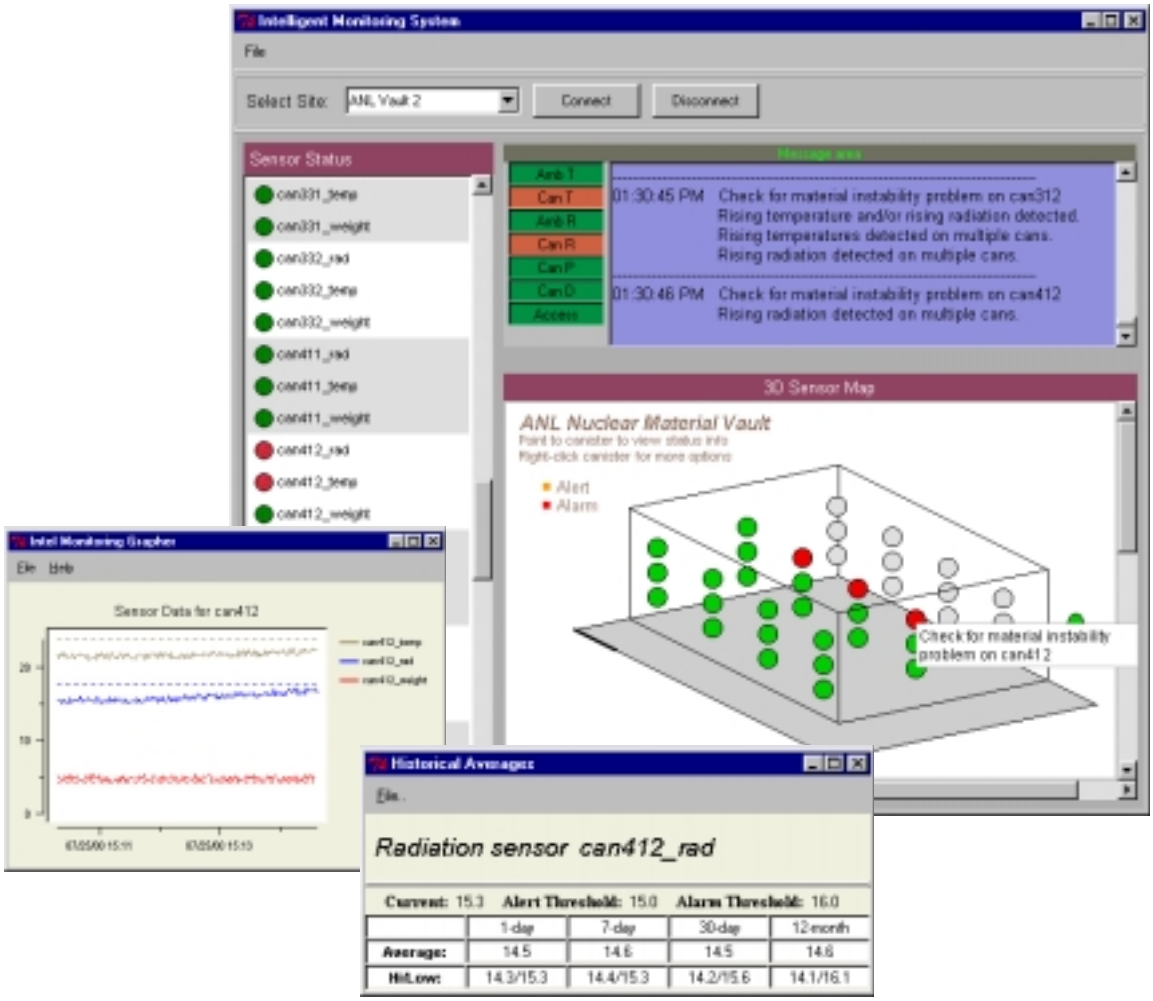
The Expert System, together with other software modules for data reduction, communication and analysis, has been incorporated within a central user interface. The integrated monitoring interface, shown in Figure 2, combines the prototype analysis modules and tools for users to query data and verify system conclusions. The interface is designed to allow operators, supervisors, inspectors, etc. to monitor facility information from a remote location. Visual queues are provided to indicate alerts and alarms and highlight relevant information. The idea is to allow the user to quickly and easily view details of an alert/alarm in order to independently assess the situation, confirm or reject system conclusions or perform further analysis.

TESTING

To demonstrate use of the prototype system for remote monitoring applications, a web interface was created and is shown in Figure 3. Through this interface, simulated scenarios can be remotely initiated and monitored. Once the simulation has been started via the web page, the Intelligent Monitoring System is launched on the local computer. Data is collected by the Intelligent Monitoring System using industry standard http methods. For demonstration purposes no security features have been included, however, encryption technology can be easily incorporated within the system for secure data transfer.

Testing of the prototype system has been conducted using simulated data for three basic safeguards scenarios: material tampering or diversion, material stability and sensor failure. In preliminary testing, the basic scenarios were simulated with the key items involved varied. For example, several runs of the material instability scenario were conducted with different canisters

designated as unstable. In all cases the prototype displayed appropriate messages correctly identifying the scenario and indicating the location of the problem canister(s). Each of these tests used pre-set files with sensor settings defined at start-up. Further testing using interactive, dynamic sensor modifications is necessary. Also, the preliminary tests were based on short term events. Potential benefits of long term trending and analysis to identify protracted events needs to be explored.



CONCLUSION

Intelligent systems for automated monitoring and analysis of safeguards-related data will be essential for future domestic and international safeguard applications. The Intelligent Monitoring System described in this paper features advanced software components for the synthesis and analysis of nuclear material safeguards related data which enhance an operator's ability to detect and respond to potential safeguards incidents. An Expert System analysis module is the core of

the system with a knowledge base generated from interviews with MC&A and security professionals. Developed using simulated sensor data representing key safeguards scenarios, the Expert System performs analysis of data and sequences of events to detect subtle inconsistencies or abnormal operating patterns and provides extended diagnostic capabilities. Demonstration of the use of such a system in remote monitoring applications is included.

Although long term development of the Intelligent Monitoring System is targeted at international safeguards applications, the techniques and algorithms for intelligent monitoring can be adapted and applied to a variety of laboratory environments and can be used to monitor experiments, processes or even ESH parameters. By implementing user-defined rules and allowing users to select algorithms ranging from simple threshold checking to complex statistical routines, a customized intelligent monitoring system can be constructed. Continued development will depend on finding collaborators with facilities for real-time testing of the intelligent monitoring system algorithms and techniques.