SAND97-1874C
SAND--97-1874C

Data Analysis for Remote Monitoring of Safeguarded Facilities

Sharon M. DeLand
Sandia National Laboratories[i]
Albuquerque, NM, 87185

CONF-970744--17

Abstract
The International Remote Monitoring Project (IRMP) sponsored by the US DOE allows DOE and its international partners to gain experience with the remote collection, transmission, and interpretation of safeguards-relevant data. This paper focuses on the interpretation of the data from these remote monitoring systems. Users of these systems need to be able to ascertain that the remote monitoring system is functioning as expected and that the events generated by the sensors are consistent with declared activity. The initial set of analytical tools being provided for IRMP installations this year include a suite of automatically generated views of user-selected data. The baseline set of tools, with illustrative examples, will be discussed. Plans for near-term enhancements will also be discussed. Finally, the applicability of more advanced analytical techniques such as expert systems will be discussed.

Introduction

The International Remote Monitoring Project (IRMP) sponsored by the US DOE allows DOE and its international partners to gain experience with the remote collection, transmission, and interpretation of safeguards-relevant data.[1,2] In addition, research and development of new technologies for integrated monitoring systems are performed under the Modular Integrated Monitoring System (MIMS) project, also sponsored by US DOE. Advances made in remote monitoring system technology under MIMS will be transferred to existing and future IRMP installations. Details of the IRMP and MIMS systems are given elsewhere.[3-7] This paper describes the data analysis utilities provided in the MIMS 1.0 software. Potential near-term enhancements are also discussed.

The MIMS Data Analysis Utilities

The purpose of the MIMS 1.0 data analysis utilities is to provide an initial, standard suite of tools that will be useful for a broad range of potential system installations. To keep the tools generically useful, they provide no automated interpretation of the data, but instead generate a variety of views of the data that can help the user assess the situation at the site. The tools fall into three major categories:

- System Operation - Options the user should use to make sure the monitoring system is functioning as expected. These are used at the initial system set-up and periodically thereafter to help validate the site data.
- Inspection - Options the user should use to actually monitor the site. These options help identify "unusual" events for further investigation.
- Site Specific - Non-general analyses designed for one or perhaps a handful of sites. Currently, there is only one such option which will be discussed below.

A detailed list of the implemented options is provided in Table 1 and three illustrative examples are given below. It is important to note that the analysis options implemented in MIMS 1.0 were intended as an initial suite of tools and not a comprehensive list. It is hoped that this paper will

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Table 1: Analysis Options in MIMS 1.0

Category	Option	Description
System Operation	Plot Analog Data as a Function of Time	Allows the user to plot data from up to six analog devices (e.g., radiation sensors) as a function of time.
System Operation	Make Scatter Plot of Analog Data vs. Analog Data	Allows the user to plot data from one sensor vs. that from another sensor (e.g., radiation counts vs. temperature).
System Operation	Compare the Number of Events per Day	Allows the user to compare the number of events of different type generated by the same sensor. This allows the user to check that events that should be paired (such as a "door close" for every "door open") are indeed paired.
System Operation	Events Reported by a Specific Sensor	Displays the number of messages reported by the specific sensor chosen by the user.
Inspection	Data Acquisition Events	Plots the number of Data Acquisition System events (e.g., "Start" and "Stop") per day. Under normal operation, these events should only be generated by the inspector responsible for the site. A check of this graph can show if there have been any unexpected termination/restarting of the data acquisition system.
Inspection	Number of Events per Hour	Makes a histogram of the number of events vs. the time of the day the event occurred. Events that occur during off-hours should be investigated.
Inspection	Material Alarm Events	Plots the number of events per day categorized as Material Alarm Events (e.g., events from a seal on nuclear material). This can show the user on which day(s) he should focus his review
Inspection	Material Status Events	Plots the number of events per day categorized as Material Status Events (e.g., events from a radiation sensor). This can show the user on which day(s) he should focus his review
Inspection	System Alarm Events	Plots the number of events per day categorized as System Alarm Events. This can show the user on which day(s) he should focus his review.
Inspection	System Status Events	Plots the number of events per day categorized as System Status Events (e.g., start or stop events from the DAS). This can show the user on which day(s) he should focus his review
Inspection	Events by Sensor Type	Creates a table of the number of alarms for the sensors of the selected type(s).
Inspection	Compare Events from Different Sensors	Allows the user to compare the number of events per day from different sensors in order to look for patterns in the sensor behavior.
Site Specific	Hot Cell Radiation	Plots data from a radiation sensor and attempts to label the graph with various steps in a fuel transfer process. This option was implemented for the then-proposed installation of MIMS 1.0 at the Embalse. Nuclear Power Station.

engender discussions between DOE and its international partners about additional appropriate analyses.

Each analysis option guides the user in selecting appropriate data sets based on time periods, specific sensors or sensor types, and sensor event types. This is intended to keep the tools user-friendly and to ensure that all users perform the analyses in a similar fashion for the sake of comparison. The utilities are implemented in Visual Basic™[ii] using Graphics Server™[iii] for the graphs. The Graphics Server™ tool provides a basic set of statistical analysis tools and allows the user to change many aspects of the appearance of the graph (titles, markers, graph type, ranges on the axes, etc.).

Example Analyses

Examples of three of the analysis options -- one from each category -- are given below. MIMS 1.0 has not yet been installed at an actual site and therefore the data shown here comes from the MIMS test laboratory. In situations where the test data did not give realistic results for demonstrating the analysis option, simulated data was used.

Example "System Operation" Option: Scatter Plot

Analyses of the system operation are directed toward determining if the system is performing as expected. This includes checking that sensors perform as expected, that triggered images are captured as expected, that all messages are recorded, etc. One method for checking sensor behavior is to do a scatter plot to see if the sensor readings appear to be dependent on environmental characteristics such as temperature. Note that some of the IRMP installations are outdoors where environmental characteristics vary more widely than in indoor facilities.

Suppose that a user has observed what appear to be diurnal variations in the radiation levels recorded at an outdoor storage silo. The sensor network includes a reasonably co-located temperature sensor that has recorded the temperature at the same time the radiation levels were recorded. Relatively large daily temperature variations have been observed.

The user decides to do a scatter plot to see if the radiation sensor shows a temperature dependence. Figure 1 shows the simulated results for such a situation (this scenario is based on a similar situation at one of the IRMP installations). The plot shows an approximate linear dependence. Use of this radiation sensor in a safeguards-like system would probably require use of a temperature correction so that the significance of a radiation reading could be understood independent of the ambient temperature. Such plots can be used to verify that the sensor is performing within the manufacturer's specifications.

Example "Inspection" Option: Number of Events vs. Time of Day

An inspector using a remote monitoring system will want to periodically review the data and identify any unusual events that need to be investigated. One way to pick out unusual activity is to consider at what time of day events occur. A facility that utilizes a single work shift for its personnel would not be expected to have any significant events occurring during off-hours; those events that do occur during off-hours should be investigated. Figure 2 shows a graph of the total number of events vs. time of day in the test lab over the course of two days. Time of day is reported in Greenwich Mean Time (GMT). Subtracting the 7 hour time difference from Mountain

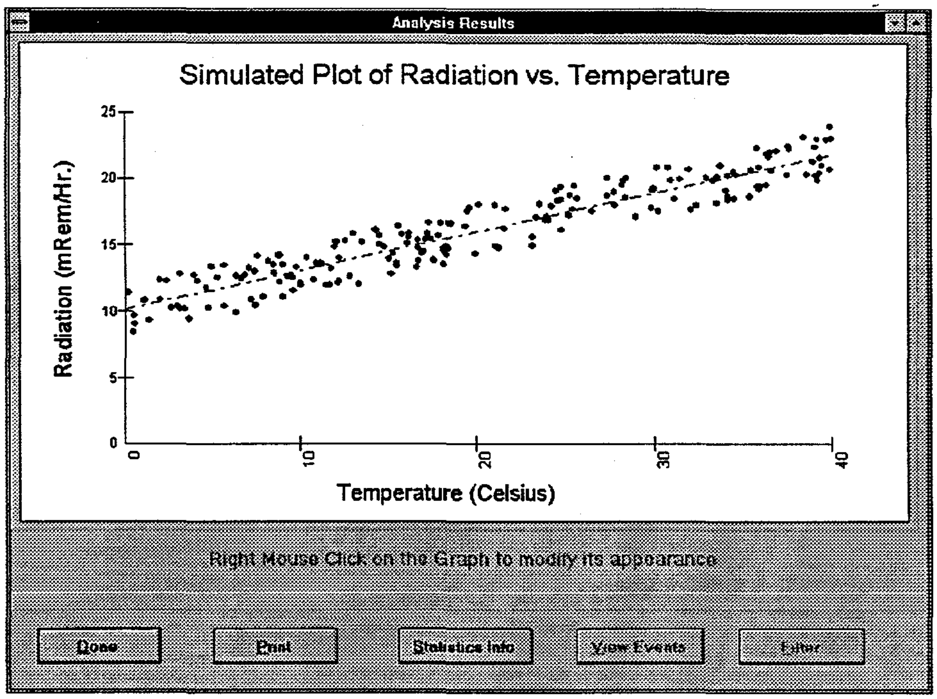

Figure 1: Scatter Plot of Radiation Level vs. Temperature using simulated data. The dashed line shows the best fit line with a slope of 0.290 and an intercept of 10.226.

Standard Time to GMT, we find that peak activity occurs during normal working hours. Activity during off-hours is largely due to periodically-generated radiation readings and state-of-health messages. Activity during working hours is comprised of sensor triggers due to movement in the laboratory.

Example Site Specific Option: Hot Cell Radiation for One Spent Fuel Transfer
This option was implemented as an example of a site-specific automated analysis for the then-proposed installation of MIMS 1.0 at the Embalse Nuclear Power Station in Argentina. MIMS was to be used to monitor transfer of spent fuel from a cooling pond to dry storage. In this option, radiation levels in a hot cell are analyzed to determine what step in the fuel transfer process they are associated with. The result for simulated data is given in Figure 3. The analysis is essentially rule-based, where the rules incorporate expected radiation levels at the various stages of the process.

Future Enhancements
There are several key enhancements that could be made to the analysis utilities in MIMS 1.0. In addition to expanding the initial suite of analysis tools, more interaction could be added to allow the user to pursue anomalous events and try to determine their cause. The ability to build custom analyses would also be a significant enhancement. The latter enhancement could most easily be achieved by integrating one of the many commercial data analysis packages available, although the details of how to keep the look and feel of the data review interface consistent and how to pass the data to the commercial analysis package remain to be resolved.

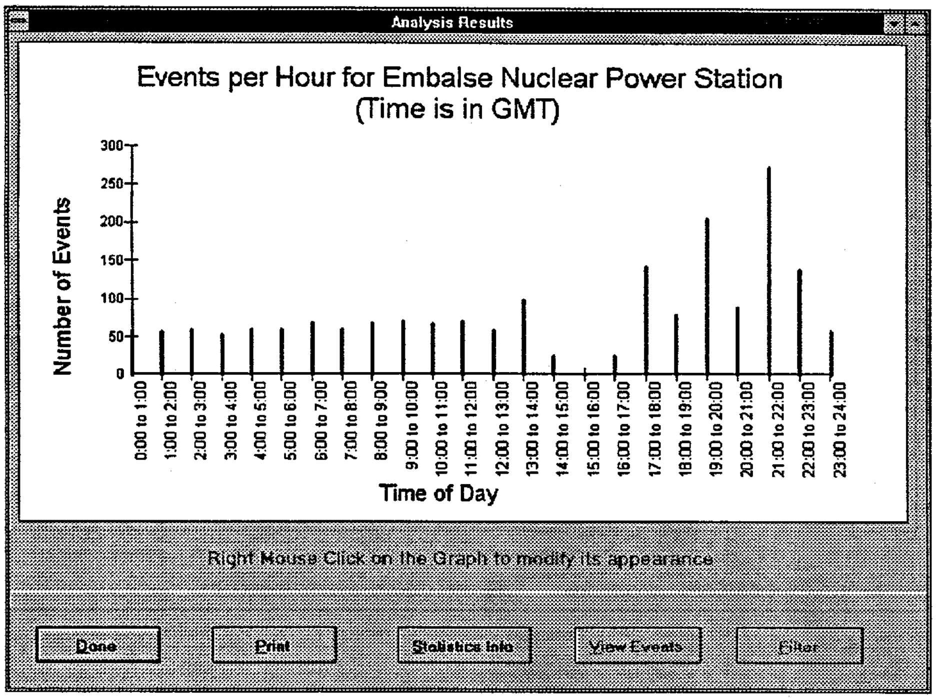

Figure 2: Graph of the Number of Events vs. Time of Day (GMT). Peak activity occurred during normal working hours as expected. Activity during non-working hours is due to periodic radiation readings and state-of-health messages.

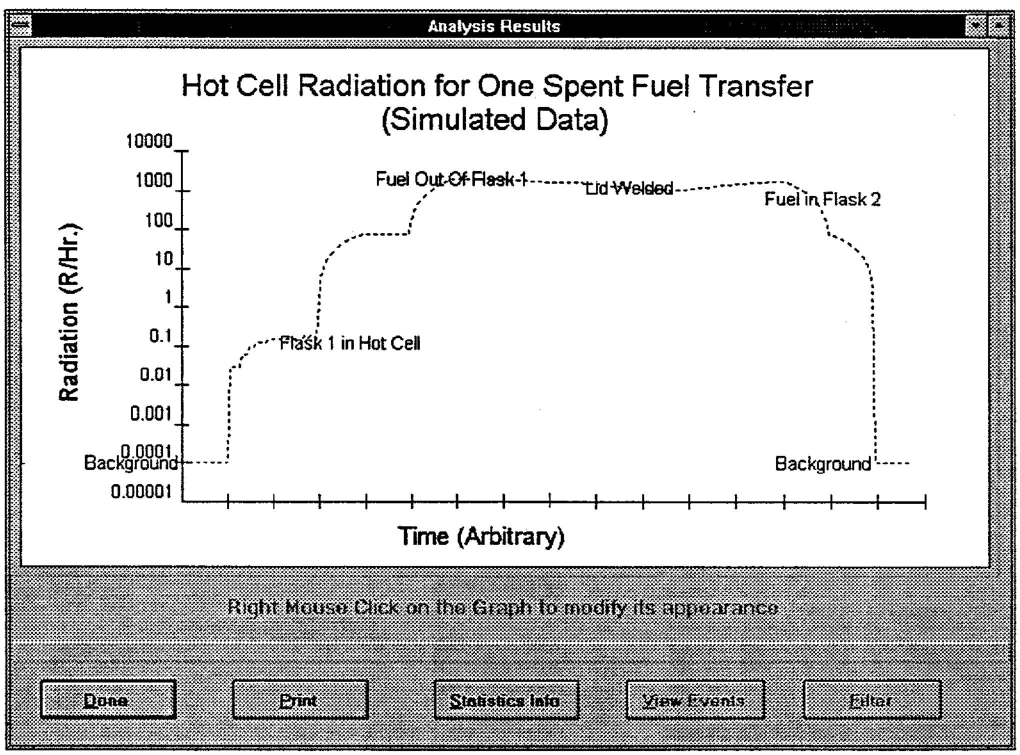

Figure 3: Example analysis of the hot cell radiation at the Embalse Nuclear Power Plant

Beyond extensions to the baseline utilities, the most significant need in the data analysis arena is for automated interpretation of the data such that the system can provide a summary of observed events in terms of expected activities and anomalous events. The use of sophisticated analysis techniques such as neural networks, expert systems, fuzzy logic, etc. is clearly applicable.[8] The key challenge lies in the fact that useful automated interpretation of the data in terms of declared activities requires extensive knowledge of site activities, the sensor signatures of those activities, and the sensor layout. While advanced analysis techniques can be used to identify an event sequence as a particular activity, it is much more difficult to make the analysis algorithms generic enough that they can be reconfigured in the field to the specifics of different sites.

Summary

The purpose of this paper was to describe the analysis methods implemented in MIMS 1.0 and to generate discussion about what types of analyses are useful for remote monitoring of safeguarded facilities. The key challenge for the future is to provide highly automated interpretation of the data for end users.

Note: Identification of specific commercial products in this paper is for information purposes only and is not an endorsement.

References

1. Sandia National Laboratories, "International Remote Monitoring Project Plan." April 1995.
2. Sandia National Laboratories, "International Remote Monitoring Project Plan." March 1996.
3. C. Sonnier and C. S. Johnson, "Safeguards Equipment of the Future - Integrated Monitoring Systems and Remote Monitoring," *Proceedings of the 35th Annual Meeting of the INMM*, pp. 808-813 (1994).
4. C.S. Johnson, M. Sallstrom, G. af Ekenstam, "The International Remote Monitoring Project - Results of the Swedish Nuclear Power Facility Field Trial," *Proceedings of the 36th Annual Meeting of the INMM*, pp. 983-987 (1995).
5. K. Veevers, D.L. Sorokowski, C.S. Johnson, S.J. Veitch, "The International Remote Montioring Project - Results of the Australian Dry Spent Fuel Storage Facility Field Trial", *Proceedings of the 36th Annual Meeting of the INMM*, pp. 976-982 (1995).
6. A. Bonino, S.F. Moreno, L. Pizarro, J.L. Schoeneman, S. A. Dupree, R. L. Martinez, C. Maxey, "The International Remote Monitoring Project - First Results of the Argentina Nuclear Power Station Field Trial," *Proceedings of the 36th Annual Meeting of the INMM*, pp. 988-996 (1995).
7. D.R. Funkhouser, G.W. Davidson, and S.M. Deland, "Modular Integrated Monitoring System (MIMS) - Architecture and Implementation" *Proceedings of the 38th Annual Meeting of the INMM* (1997).
8. See for example:
   J.A. Howell, "Analysis of Facility Monitoring Data", Los Alamos National Laboratory, LA-UR-96-2571. Presented at the Institute of Nuclear Materials Management Annual Meeting, Naples FL, July 1996.
   J.A. Howell and C. Fuyat, "Neural Information Processing and Self-Organizing Map as a Tool in Safeguarding Storage Facilities," *Proceedings of the 34th Annual Meeting of the INMM*, pp. 187-194 (1993).

---

[i] Sandia National Laboratories is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL8500.

[ii] Visual Basic is a trademark of Microsoft Corporation in the USA and other countries.

[iii] Graphics Server is a trademark of Bits Per Second Ltd.

DOE/ER/13432--T1

RECEIVED
AUG 28 1997
OSTI

John P. Selegue
Department of Chemistry
University of Kentucky
DE-FG05-85ER13432

Metallacumulenes and Carbide Complexes
Final Performance Report

DOE support for our research on metallacumulenes and carbide complex began in September, 1985 and ended in December, 1992. We investigated many aspects of transition metal complexes of carbon-rich ligands. These included cumulated transition metal carbene complexes of the types vinylidene ($M=C=CR_2$), allenylidene ($M=C=C=CR_2$) and butatrienylidene ($M=C=C=CR_2$), as well as "naked" carbon ligands C_1, C_2 and C_3. In the last 3 years, we began to put some of our effort into studying the fullerenes, a series of newly discovered, molecular allotropes of carbon. Finally, we investigated initial aspects of the coordination chemistry of thiophenes, from the perspectives of (1) modeling the transition-metal-catalyzed hydrodesulfurization of fossil fuels, and (2) development of metal-doped, polythiophene-based polymers.

I. Vinylidenes

A. Iron, Ruthenium and Osmium

1. Alkyne to vinylidene rearrangements

The ethyne to vinylidene ($HC\equiv CH \rightarrow C=CH_2$) rearrangement is a fundamentally important transformation which is strongly endothermic in the gas phase. On certain metal surfaces and metal complexes, ethyne converts spontaneously to vinylidene. For example, reactions of $[M(PR_3)_2(Cp)]^+$ (M = Fe, Ru, Os) sources with 1-alkynes normally lead to vinylidene complexes $[M(C=CR'H)(PR_3)_2(Cp)]^+$ without observed $[M(\eta^2\text{-}R'C\equiv CH)(PR_3)_2(Cp)]^+$ intermediates, especially for large phosphine ancillary ligands such as PPh_3. However, we discovered that metastable η^2-ethyne complexes of certain sterically nondemanding $[M(PR_3)_2(Cp)]^+$ metal centers could be isolated, and the rearrangements of these complexes to their more stable vinylidene forms could be followed by NMR. This study was begun by Ph.D. student Kevin Frank and completed by Ph.D. student Jeffrey Lomprey. They found (Scheme 1) that the complexes $[MX(PR_3)_2(Cp)]$ (MX = FeI, RuCl; PR_3 = $P(OMe)_3$, PMe_3, PMe_2Ph, 1/2 *o*-$(PMe_2)_2C_6H_4$, 1/2 $Me_2PCH_2CH_2PMe_2$) react with ethyne in polar media to form metastable η^2-ethyne complexes (**1**, R = H) which gradually rearrange to the thermodynamically favored vinylidene form (**2**, R = H). For 1-alkynes such as propyne or phenylethyne, vinylidene complexes **2** were isolated with no trace of η^2-ethyne species.