Title: APPLICATIONS OF INVENTORY DIFFERENCE TOOL AT LOS ALAMOS PLUTONIUM FACILITY

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APPL CATIONS OF INVENTORY DIFFERENCE TOOL
AT LOS ALAMOS PLUTONIUM FACILITY

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Abstract

A prototype computer program reads the inventory entries directly from the Microsoft Access database. Based on historical data, the program then displays temporal trends and constructs a library of rules that encapsulate the system behavior. The analysis of inventory data is illustrated using a combination of realistic and simulated facility examples. Potential payoffs of this methodology include a reduction in time and resources needed to perform statistical tests and a broad applicability to DOE needs such as treaty verification.

Introduction

To establish a cost-effective safeguards system at Los Alamos Plutonium Facility and to evaluate a different approach to setting control limits for inventory differences, an automated computer tool capable of looking at data over time is needed. The basic requirements that the computer tool should satisfy are (a) replacement of expert's judgment by an automated tool; (b) conversely, verification by experts of anomalous events in the data flow; and (c) savings in time and manpower in data evaluation. A material balance is drawn around each batch processed at the Plutonium Facility and each batch is individually critiqued via propagation of variance of the measurement uncertainties of all feed, residue and product items. This effort is very time consuming and at this point in time very labor intensive. A preliminary scheme has been devised in which anomalous events, relevant to abrupt diversion related to an individual batch, are detected by comparing the observed mass balance on each batch with the established patterns for that process, encapsulated in a library of rules. This type of tool would allow accountability personnel to monitor each material balance closing on a daily basis, giving very timely detection. The long-term trends, such as occur in protracted diversion, are analyzed by filtering out the oscillations in the data flow, coupled with statistical tests—chiefly Page’s test. Finally, we use the contingency tables to correlate the material type and the measurement type, thus eliminating erroneous entries in the accounting records.

The principal objectives of an accounting system for safeguarding nuclear materials are: (a) to provide assurance that all material quantities are present in the correct amount; (b) to provide timely detection of material loss; and (c) to estimate the amount of any loss and its location. Inventory difference \( M_n \), also known as material unaccounted for (MUF), for an arbitrary period \( n \) is written as

\[
M_n = I_n - I_{n+1} + T_n ,
\]

where \( I_n \) is the measured inventory at the beginning of period \( n \) and \( T_n \) is the net transfer measurement for period \( n \). At Los Alamos Plutonium Facility the inventory difference at the end of each month is calculated as a sum of material adjustments pertinent to each account and process and represents the sum of the closing balances of the individual batches in each process. Traditionally, the materials
accounting for safeguards has been a subject of statistical-analysis and decision-making techniques. For example, in the case of protracted diversion, Page's test has successfully been applied; on the other hand, when the diversion is abrupt the Kalman filter has proven to be an adequate tool of analysis. In recent years, an increased use has been made of the rule-based forecasting systems, the most popular of which is a fuzzy controller. Both the classical statistical tools and the ideas of the rule-based systems have earlier been described to some detail.

Data Structure

The accounting system at Los Alamos Plutonium Facility is implemented as a collection of database records following nuclear material transactions in time. For a given account, describing the material balance area, a process status separates items according to the process, type, or use. Each transaction contains the transfer information, denoted XNM, giving the amount of nuclear material transferred, as well as the from inventory amount FNM and to inventory amount TNM, at the end of transaction.

To illustrate these concepts, let us assume that 100 g of plutonium has been subject to a batch process that, due to an uncontrollable holdup, resulted in a final amount of 80 g of the material. The initial amount of plutonium, the batch amount, and the final amount are recorded as three separate transactions, having the following values of the three database fields.

Table 1. The Values of Three Numeric Fields for Sample Transactions

<table>
<thead>
<tr>
<th>Record</th>
<th>XNM</th>
<th>FNM</th>
<th>TNM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>20</td>
<td>0</td>
</tr>
</tbody>
</table>

Note that Record 1 simply describes the transfer of 100 g plutonium (XNM = 100) from the initial state to the batch state; the from amount at the end of this transfer equals 0 (FNM = 0), whereas the to amount is 100 (TNM = 100). In the batch process, described by Record 2, in which 20 g of plutonium are lost, only the remaining 80 g are transferred (XNM = 80). The from amount at the completion of this transaction is thus 20 (FNM = 20), whereas the final to amount is 80 (TNM = 80). (In a hypothetical situation, in which we gain some amount of plutonium, the from amount would become negative.) Finally, Record 3 describes the inventory adjustment: the loss of plutonium is described by a positive value of the FNM field.

Test Results

The sample results reported in this section refer to a process, called burning metal, at one of the Plutonium Facility material balance areas. From a database containing three months of data, we have selected the records for which an inventory adjustment was made due to a cleanup of the material. The
cleanup records form, obviously, a small subset of the set of records pertinent to this process status and balance area. In Figures 1-3, we show the values of the three numeric fields in the database as a function of measurement number.

**Figure 1.** Amount of the transferred nuclear material as a function of measurement number.

**Figure 2.** Amount of the from nuclear material as a function of measurement number.

**Figure 3.** Amount of the to nuclear material as a function of measurement number.
We now draw the control limits—both for the mean and range—using the from amount, shown in Figure 2. The results in Figures 4 and 5 show the control limits for the mean and range constructed out of three consecutive records. Figure 6 illustrates the results of the Page’s test, in which the value of the false alarm probability is 0.05, whereas the amount of diversion we wish to detect is one standard deviation.

![Figure 4. The control chart for the mean.](image)

![Figure 5. The range control chart.](image)

![Figure 6. Two-sided Page's test with false alarm probability of 0.05.](image)
To reduce the effect of irregularities on forecasting, we correlate the amount of material transfer with FNM and TNM measurements by forming the product of their forecast errors, as indicated in Figure 7. The advantage of this approach is that when one of the three factors of the product is small, the product is small too. In other words, only when all the factors are anomalous will their product show an anomalous behavior.

![Figure 7. Correlated forecast error of XNM, FNM, and TNM.](image)

The correlated forecast error reduces significantly the number of anomalies, thus becoming a practical tool that does not trigger too many false alarms. It is our method of choice for detecting an abrupt diversion.

**IV. Conclusions**

Our ultimate goal is to provide an automated computer tool capable of looking at data over time to establish a cost-effective safeguards system at Los Alamos Plutonium Facility, as well as other DOE facilities. This tool should supplement, and eventually replace, the existing visual methods of looking at the nuclear material accounting databases. Furthermore, it should be able to detect both the protracted and abrupt diversions and the inconsistencies in the data. The methodology, together with a prototype computerized tool, has been demonstrated by combining different techniques used in the process of database analysis.

**References**


