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DATA PROCESSING SYSTEM FOR EXTERIOR INTRUSION
DETECTION SENSOR EVALUATION AND DEVELOPMENT

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Abstract

The data processing system has been developed to analyze data collected at the Small Laboratories exterior intrusion detection test facility for the evaluation of sensors and the development and testing of alarm processing and signal processing algorithms. This data system will aid in alarm processing and attempts to compensate for sensitivities or shortcomings of sensors used in an intrusion detection system, and signal processing, which attempts to discriminate between intruders and other sources of excitation. Analyses and alarm data from the sensors and meteorological data are collected by a microcomputer-controlled data acquisition system. The data are stored in three data bases to facilitate later processing and analysis. For example, alarm rates as functions of meteorological conditions can be determined, the range of alarm rates experienced by the sensors can be presented, and the range of signals from sensors can be plotted. The evaluation of sensors includes the determination of sensitivity to environmental conditions. Examples of the capabilities of the system are presented.

Most sensors currently available use motion and filtering and threshold or time techniques to generate the alarm signal. The use of more sophisticated signal processing techniques could be used to discriminate between the analog signals produced by sources of false and nuisance alarms and those signals produced by valid intruders.

Sandia Laboratories sensor test field and laboratory provide data on exterior intrusion detection sensors. These data are regularly reported in the Intrusion Detection Systems Handbook¹. As part of this laboratory, a data collection and analysis facility has been developed for (1) the characterization and evaluation of intrusion detection sensors, (2) the development of alarm processing algorithms, and (3) the study of sensor signal processing techniques.

In order for sensors to be characterized and evaluated, data from these sensors are collected automatically over the range of occurring weather conditions. These data are recorded in a format compatible with computer analysis; therefore, the performance of any sensor as a function of any of these weather conditions or time can be readily obtained.

Achievement of the desired level of security with a perimeter intrusion detection system often requires the use of sensors of more than one technological type in each sector. Alarm processing involves combining the alarm outputs of different sensors in the same sector or the alarm outputs of the same type of sensor in different sectors to achieve lower false and nuisance alarm rates, while maintaining or improving probability of detection.

TEST FIELD

The test field for exterior sensor evaluation and development (Figure 1) is being constructed to include many of the characteristics found in operational security systems, such as double fences, fence corners, a personnel entry point, and a vehicle entry point. The field includes three 100 metre sectors and one 50 metre sector. The facility includes closed-circuit television for alarm assessment and lights to provide 24-hour operation.

Most intrusion detection sensors consist of a sensing element and an electronic processor. The sensing element usually produces an analog signal in response to changes in the physical parameter being detected. For example, in the case of buried seismic sensors, pressure is the parameter which is measured. The electronic processor amplifies the analog signal and produces an alarm signal (bifurcated signal or relay closure) when the

Figure 1. Test field (artist's conception)

analog signal meets the conditions for which the processor was designed. The analog signal is not normally available outside the processor, but some of the sensor processors used have been modified so that this signal is available. The alarm and analog signals from the sensors are routed on twisted shielded pair cables to the data acquisition system. Line driver amplifiers are used at the sensor end of the analog lines to provide isolation, and filters and lightning protection devices are used at the data acquisition end to prevent signal degradation. The data acquisition system can record both analog and alarm data from a maximum of 48 sensors.

DATA COLLECTION

The Adaptive Intrusion Data System (AIDS) is a computer-based data collection system which was designed and built to automatically collect large quantities of data from a variety of intrusion sensors². The data is recorded on digital magnetic tape and includes the bilevel signals, the analog signals from selected sensors, and the weather conditions. These data assist in the characterization of sensors and alarm processing by providing the data needed to correlate alarms with weather conditions or with other alarms. In addition the analog data can be used to evaluate the electronics processor.

Data are recorded each time an alarm occurs and once every 10 minutes in order to provide information on the background weather conditions. When an alarm occurs, the video tape recorders are turned on for 7.5 seconds and the time and the sensor number are printed. Data are recorded from 1.5 seconds prior to occurrence of the bilevel alarm signal to 4.5 seconds after the signal by using the mass memory as a data buffer.

A functional block diagram of AIDS which illustrates the major components of the system and the major data and control paths between these components is shown in Figure 2. The major components of AIDS and their functions are given in Table I.

Figure 2. Control and data paths in AIDS

Table I
Major AIDS Components

Component	Function
Nova minicomputer	System controller
Video subsystem	Records video images of the sensor field
Bilevel processor	Monitors alarms
Analog signal conditioner	Digitizes analog signals
Memory controlled data processor	Formats data for tape
Mass memory	Provides 1.5 second delay
Time clock	Provides time
Metro	Provides weather conditions
Magnetic tape	Digital recording medium

DATA ANALYSIS FACILITY

The equipment used for the data analysis consists of a Nova minicomputer with two 7-track magnetic tape drives, a 10 megabyte disk drive, and a Tektronix 4051 graphics terminal for plotting.

DATA STORAGE AND RETRIEVAL CAPABILITIES

DATA STORAGE

The data collected with the AIDS are stored in two data bases. The alarm data base is used for storing alarm data (time, weather conditions, assessment, etc.), while the analog data base is used to store the analog signals from sensors.

The Alarm Data Base

The alarm data base is used to aid in the characterization of sensors and the development of alarm processing algorithms. The characterization of sensors requires that the time and the associated weather parameters for each alarm, as well as the background weather conditions that each sensor experiences, be recorded. The background weather conditions are required to compute weather-induced alarm rates. When an alarm processing algorithm is tested, the time and the associated weather conditions for each alarm must be stored in a manner which facilitates simulating the operating conditions during the alarm.

The structure developed to fulfill these needs consists of two parts: alarm information and background weather conditions. Alarm information consists of a list of alarm entries ordered by time of occurrence. Each entry contains the sensor number, the day and time of the alarm (to the tenth of a second), the weather conditions at the time of the alarm (temperature, wind speed, wind direction, humidity, rainfall rate, potential gradient, and rainfall amount), an assessment, and an event number. The time and weather conditions are recorded on magnetic tape at the time of the alarm by the AIDS. An entry which indicates the assessment (i.e., rabbit, person, tumbleweed, vehicle, etc.) is added after the video tapes recorded at the time of the alarm have been viewed.

A record of the weather conditions during the operating time of a sensor provides background weather data for each sensor. The background weather conditions for each weather parameter are stored independently, with the exception of wind speed and wind direction, which are stored jointly. Because of storage limitations, the range of possible values for each parameter is divided into a small number of subranges. For example, the background data for wind speed are stored in separate 5-mph subranges such as 20 to 24 mph, 25 to 29 mph, etc. For each subrange, a count is stored which corresponds to the number of background weather recordings during which the value of that parameter was within the particular subrange. If the wind speed for a background recording was 27 mph, the count in the 25 to 29 mph subrange would be incremented. The alarm rate can then be calculated simply by dividing the number of alarms during which the weather parameter fell into a subrange by the total number of hours during which those subrange values were observed.

The Analog Data Base

Currently, the analog data base is limited to graphical plots of selected analog signals. In the future, selected signals will be stored on disk and magnetic tape. The analog signal for each sensor will be stored on a separate tape so that minimal time will be required to locate the appropriate signal. The time, weather conditions, and assessment associated with each analog signal will also be stored on the same tape to facilitate identification.

PROGRAMS FOR CHARACTERIZING SENSORS

Computer Programs

The characterization of sensors requires that the causes of false alarms be determined and that the alarm rates, as a function of these causes, be presented rapidly and easily. Several computer programs have been written to obtain and display this information from the data base. These programs include DUMPALARM, DUMPBK, and ALARM.

The DUMPALARM program is used to obtain a summary of the data base and to list the alarms in the data base. The summary is used primarily for diagnostic and recordkeeping purposes. The listing portion is used to verify that the alarm data were inserted correctly.

The DUMPBK program examines the background weather data. This program lists the number of background samples for each range of weather conditions for the specified sensor.

ALARM is an interactive program which is used to select and display alarm and alarm rate information for selectable user-specified conditions. After the program is started, selection and display are initiated by typing an instruction of the form COMMAND,PARAMETERS,VERSUS. The COMMAND section of this instruction can be used to select histograms of the data, a listing of all alarms, or histograms of background data. The PARAMETER section is used to select which alarms are to be displayed and, in the case of histograms, whether the number of alarms or the alarm rate is desired. In a histogram, either the alarm rate or the number of alarms is plotted against a parameter such as time or wind speed. The VERSUS section of the command line is used to specify this parameter.

Command Structure for Program ALARM

The COMMAND portion of the instruction for program ALARM can be HIST for histograms of the data, LIST for a listing of selected alarms, or BACK for histograms of background data.

In the PARAMETER portion of the instruction, most parameters are accompanied by arguments which identify desired values. The parameters and the values which the arguments can assume are shown in Table II.

Figure 5 presents the number of alarms for all sensors. The system can record data from up to 48 sensors; only 12 sensors were operational during the period of time the data in Figure 5 were collected. The command which produced this plot is written at the top of the plot.

Figure 5. The number of alarms for each sensor

Figure 6 shows the number of alarms on sensor number 5, which is a fence sensor, as a function of wind speed. The primary source of false alarms on this sensor is wind; however, the plot shows that 12 alarms occurred when the wind speed was between 0 and 4 mph. During the time of recording, some work was being done on the field and the fences and most of these alarms were caused by the workmen. These alarms were assessed as being caused by the workmen, but were not removed because the software to select alarms by assessment was not complete at the time these plots were made. The plot also shows that as the wind speed increases, the number of alarms increases for speeds up to 30 mph and then decreases for speeds above 30 mph. However, as shown in Figure 7, the wind speed seldom rose above 25 mph. Figure 8 shows the alarm rate for the same sensor as a function of wind speed. This plot was calculated by dividing the number of alarms in a given range (from Figure 6) by the number of hours the wind speed was in that range (from Figure 7). Because the wind speed was below 10 mph most of the time, the alarm rate for these wind speeds was effectively zero in comparison to alarm rates for higher wind speeds.

Figure 6 shows that 15 alarms occurred when the wind speed was above 30 mph. However, Figure 8 shows the alarm rate is zero above 30 mph. The reason for this apparent discrepancy is that the background weather data are recorded at regular 10 minute intervals rather than at the time of an alarm. For example, assume that two background weather samples (taken 10 minutes apart) indicate a wind speed of 27 and 28 mph, respectively. Further, assume that an alarm occurs during a 32 mph wind gust during the 10 minute interval between weather recordings. This set of events

Figure 6. The number of alarms on sensor 5 as a function of wind speed

Figure 7. Background wind speed data for sensor 5

Figure 8. Alarm rate versus wind speed for sensor 5

would result in two background samples with a wind speed between 25 and 29 mph and one alarm recorded as occurring at a wind speed between 30 and 34 mph. This method of background sampling is approximate for short time periods such as the one during which the data shown were collected; however, when data are recorded over a long period of time, this method does present a valid statistical representation of the weather parameters experienced.

The performance of this same sensor with respect to wind direction is illustrated in Figures 9, 10, and 11, in which the number of alarms, the background conditions, and the alarm rate are shown. These data would tend to indicate that the sensor is more sensitive to easterly winds than to winds from other directions (zero degrees is east, 90 degrees is north). Figure 8 also indicates that this sensor is sensitive to high winds. Figure 12 presents data which can be used to better understand the relationship between high winds and wind direction. This figure, the number of alarms as a function of wind direction for wind speeds greater than 20 mph, shows that there were no alarms for high winds from directions other than the east. Two possible reasons for this are (1) the sensor is sensitive only to easterly winds, or (2) there were no high winds from any other direction. This example illustrates the need for background wind data as a function of both speed and direction.

Figure 13 shows the background wind data for sensor 5. Most of the winds over 20 mph and all of the winds over 25 mph occur from directions between 90 and 149 degrees. Therefore a dependence of alarm rate on wind direction cannot be demonstrated because no data over 25 mph were available from any other directions. The data base used to generate Figure 13 contains sufficient information to present the number of alarms, the alarm rate, and the background conditions as a function of wind speed and wind direction. A computer program which will be used to provide a three-dimensional plot of these data is under development.

Figure 9. The number of alarms versus wind direction for sensor 5

Figure 10. Background wind direction data for sensor 5

Figure 11. Alarm rate versus wind direction for sensor 5

Figure 12. Number of alarms versus wind direction on sensor 5 when the wind speed was 20 mph or higher

Figure 14 shows the alarm rate for each hour of the day and illustrates how some alarm sources are related to time. In this example, rabbits are the principle source of alarms associated with this sensor. The assessment data show that high alarm rates experienced during the early hours of morning are caused by rabbits which usually roam the field at that time.

Sensor characterization also requires that the analog signal be examined in order to determine how it responds to various stimuli. The sensitivity of a buried sensor to rain is shown in Figures 15, 16, and 17. Figure 15 shows the background noise level for the sensor when it was not raining, while Figure 16 shows the noise level during a rainfall rate of about 1 inch per hour. Figure 17 shows the analog signal during a rainfall rate of about 2 inches per hour.

WIND DIRECTION	WIND SPEED									
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-45	
0-29	115	27	14	4	2	0	0	0	0	
30-59	78	8	5	2	0	0	0	0	0	
60-89	131	6	10	5	0	0	0	0	0	
90-119	379	38	20	19	9	4	0	1	0	
120-149	631	47	17	5	2	1	0	0	0	
150-179	331	26	5	0	0	0	0	0	0	
180-209	174	29	2	1	0	0	0	0	0	
210-239	179	49	7	1	0	0	0	0	0	
240-269	169	69	37	11	0	0	0	0	0	
270-299	147	60	32	16	2	0	0	0	0	
300-329	126	29	10	6	0	0	0	0	0	
330-359	122	31	14	8	2	0	0	0	0	

Figure 13. Background wind speed and wind direction data for sensor 5

Figure 14. Alarm rate versus hour of day for sensor 21

Figure 15. Analog data with no rain

Figure 16. Analog data during one inch per hour rainfall

Figure 17. Analog data during two inches per hour rainfall

ALARM PROCESSING

Alarm processing is a relatively new area of investigation which attempts to reduce the number of false/nuisance alarms, while maintaining an acceptable probability of detection. Alarm processing generally requires the use of more than one sensor to protect each sector. A system which uses alarm processing is described in Reference 3. The alarm data base described above will be used to compare the effectiveness of different alarm processing techniques.

Some alarm processing techniques include combining the alarm outputs in a given time window with AND gates, OR gates, exclusive OR gates, or priority levels, to provide better protection with lower false alarm rates. A thorough understanding of the capabilities and limitations of each sensor is needed if these techniques are used.

One technique for reducing the number of false/nuisance alarms from a given sensor in a system is to reduce the priority or importance of alarms from that sensor during periods when the weather conditions would ordinarily cause a high nuisance alarm rate. For example, the priority of sensor 5 (Figure 8) could be reduced when the wind speed is above 20 mph. During the time the priority of one sensor is reduced, the priority of the other source(s) of detection should be increased.

SIGNAL PROCESSING

Analog signals are collected to study methods for taking advantage of the characteristics of signals produced by different sources of alarms in order to discriminate between nuisance alarms and valid intruders. Standard techniques of signal processing, such as spectral analysis, correlation, etc., will be used in future studies of analog signals.

An advanced application of both signal and alarm processing techniques is the use of combinations of more sophisticated sensors whose outputs contain more information than a simple relay closure, e.g., confidence level, classification, background level, etc. This information can then be used in an alarm processing technique to provide a high probability of detection with a low false alarm rate. It is possible that all of the sensors in either one sector or two adjacent sectors could be processed by one microprocessor.

REFERENCES

1. Intrusion Detection Systems Handbook, SAND76-0554, Sandia Laboratories, Albuquerque, New Mexico, revised October 1977.
2. N. E. Corlis and C. S. Johnson, Description, Operation, and Diagnostic Routines for the Adaptive Intrusion Data System, SAND77-1029, Sandia Laboratories, Albuquerque, New Mexico, March 1978.
3. J. Jacobs, "System Control and Display," Journal of the Institute of Nuclear Materials Management, Vol. VI, No. 3 (Fall 1977), 400-410 [also published as SAND77-0996, November 1977].