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AN APPROACH TO MONITORING PERFORMANCE OF GEO-CODED MULTISENSOR DATA FUSION SYSTEM

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ABSTRACT

Performance monitoring of data fusion system of geo-coded multisensor involves monitoring the activity of the system, making management decisions and performing maintenance actions to reduce the influence of the system faults. Most of the research on the performance monitoring has concentrated on simple monitoring mechanisms related to fault monitoring. This paper considers performance monitoring of complex data fusion system of geo-coded multisensor in distributed network environment. The objective is to find an effective method for designing and implementing an advanced performance monitoring system in order to increase operation reliability and quality of the data fusion system. A functional model for implementing the performance monitoring system is discussed for solving the problem. The key issues addressed in the study include alarm correlation and performance management. This paper describes also the approach adopted in the current work and the imprint techniques for design and implementation of the performance monitoring system.

1 INTRODUCTION

Performance monitoring of complex geo-coded multisensor data fusion system in distributed network environment is very important for development of high reliable and precision positioning system in military and agricultural domains. Especially, the data fusion system of geo-coded multisensor has increased dramatically in both size and complexity in the last few years. However, the new power brought with modern information processing technology, including complex distributed network environment, creates greater vulnerability for these systems. Since faults are inevitable, quick detection, identification and recovery are crucial to make the system more robust and its operation more reliable. As the data fusion system of geo-coded multisensor becomes more heterogeneous and more hardware and software from various vendors are used, the whole picture of its specification becomes bewildering. This brings out the need for a unified approach or principles to the area of performance monitoring of the data fusion systems of geo-coded multisensor.

There are a number of fundamental problems associated with performance monitoring of the data fusion systems of geo-coded multisensor. For example, quality of fusion data depends on normal operation of the data fusion system. However, it is very difficult to obtain a global, consistent view of all components related to quality of fusion data in the performance monitoring system through simply collecting event reports. Because estimation errors of real time status of the system in the reporting of events may result in these events being processed in incorrect methods. Another problem is that the monitoring system may itself compete for limited resources with the data fusion system being monitored and so modify its behavior. To solve these problems, a performance monitoring model must be developed to describe a set of general functions for generating, processing, disseminating, and presenting monitoring information, and to guide design and implementation of the performance monitoring system.

2 DATA FUSION SYSTEM

A complex data fusion system of geo-coded multisensor is based on a distributed radio network. The No.1 device data, No.2 device data and No.2 device data are received by three closely positioned stations or network nodes. These data are used to determine a coherent assessment of the local situation. Input data are received respectively by No.1, No.2 and No.3 device sensors on each station. New input data are generated at a speed of two per second for each target identified by each sensor. In my discussion, up to 128 targets can be located in the field around these station. These targets result in 512 new objects every second. A blackboard approach can be used to complete the assessment (Miles, et al. 1989; Hayes-Roth, et al., 1989). A number of co-operating rule-based systems include the related knowledge sources. These system can create, examine, modify and delete data in certain areas of memory or the parts of the blackboard.

Each item of No.1 device, No.1 device and No.2 device data is recorded on the appropriate station blackboard. KS1(Knowledge Source 1), KS2 and KS3 attempt to consolidate No.1 device, No.2 device and No.3 device information respectively and, to maintain simplicity for real-time operation. The original records are deleted and only the similar one are counted. In this case, similar means with pre-specified tolerances of range and bearing. KS4 and KS5 attempt to maintain a simple record for the targets, each of which will be the fused result of a large

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set of spatially and temporally separated No.1 , No.2 and No.3 devices.

As the data fusion system becomes more complex, proper maintenance of the system becomes increasingly critical. In order to obtain high quality fused data from the distributed data fusion system, integrity of the system becomes also more important. The integrity is further defined as: the ability of the system to provide high quality, continuous fused data while gracefully failures of hardware and software elements of the system These elements can fail for any number of reasons, including architectural design defects, inadequate maintenance procedures, or procedural error. Intrusions can come from acts of radio interference and other accidents. Moreover, the integrity is a higher-level measurement of performance of the data fusion system that is the system's ability to operate in the presence of faults. Thus, performance monitoring of the data fusion system is an important means to assure the integrity of the system in complex radio network environment. This paper discusses only problem of the performance monitoring due to the length limitation.

3 MONITORING MODEL

A good model is a framework for design and implementation of the performance monitoring system. This model is used to determine the facilities needed to design and construct this system. Some important problems related to the model implementation include its concepts, terminology, and monitoring means. The object modeling technique (Rumbaugh, 1991) can be widely used for design and implementation of the monitoring model.

3.1 Service and Functions

The generic monitoring services built on the model are important tools for implementing the performance monitoring system and for debugging it during the system development. On the other hand, monitoring services are also essential for monitoring and maintenance process automation in this system. Thus, such monitoring model is based on a set of monitoring functions and may be used as a practical framework for implementation of the monitoring system. The main functions of the monitoring model include generation, processing, dissemination, and presentation of monitored information.

3.2 Techniques and Tasks

In the model, a monitored object in the data fusion system is defined as any hardware or software component whose behavior can be monitored by the performance monitoring system. Monitoring can be performed on an object or a group of related objects. The behavior of an object can be defined and monitored in terms of its status and events. Two kinds of monitoring techniques, time-driven monitoring and event-driven monitoring, are used respectively for acquiring periodic status information and information about the occurrence of events of interest. The monitoring model performs the following monitoring tasks.

(1)Generation: when some important events are detected, the related event and status reports are generated. These monitoring reports are used to construct monitoring traces. They represent current and historical views of activity of the data fusion system.

(2)Processing: it converts the raw monitoring data to the required format for further application.

(3)Dissemination: the monitoring reports are disseminated to the appropriate users, managers and processing agents.

(4)Presentation: gathered, processed, and formatted information is displayed to users.

3.3 Detection Mechanisms

Various detection mechanisms can be used to identify the occurrence of events. According to which mechanism is used, monitoring systems can be categorized into three types: hardware monitors, software monitors and hybrid monitors.

Hardware monitors are separate objects that are used to detect events associated with an object or a group of objects. The detection is performed by monitoring system status or by using physical sensors or probes. Hardware monitors can be successfully used for monitoring various physical parameters of components of the data fusion system, where a great deal of information is collected and processed rapidly.

On the other hand, software monitors usually makes use of simulation models or software packets to identify the occurrence of events with the help of normal information. Software monitors present information in an application-oriented manner that is easy to understand and use, compared to the raw information generated by hardware monitors. Software monitors can easily be replicated and are more flexible, portable, and easier to design and construct than hardware monitors. The disadvantage of software monitors is that their simulation models require a great deal of input data and therefor interfere in both their application area and precision of monitored data. For this reason, pure software monitors are not adequate for completing on-line, real-time monitoring tasks in the data fusion system.

Hybrid monitors are designed to employ the advantages of both hardware and software monitors, while overcoming their disadvantages. Typical hybrid systems consist of independent hardware devices that receive monitoring information from typical components of the data fusion system, and independent software models that compute more application-oriented monitoring information for these or other components.

4 ALARM PROCESSING

The faults in the data fusion system can be usually represented by relevant alarms on monitoring screen. How to determine the relationship between a number of

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alarms is one of the most important problems in implementation of the performance monitoring system with alarm correlation technique. The technique is widely used in the monitoring system. The conceptual approach to alarm correlation was discussed in (Aloni, et al., 1991). Interpretation and correlation of events has been analyzed in other areas, such as electric power systems, nuclear-power-plant alarm management (Rellano, et al., 1991), and patient-care monitoring.

4.1 Alarm Correlation

The alarms are mediated by alarm messages about faults. A fault is a disorder event or status occurring in any hardware or software component of monitored data fusion system. Faults happen within the system components, while alarms are external manifestations of faults. Alarms defined by designers and generated by the component or equipment are observable by managers of the data fusion system.

Alarm correlation is a conceptual interpretation of multiple alarms such that new meanings are assigned to these alarms. It is a generic process that underlies different monitoring tasks of the performance monitoring system. Some typical operations relevant to alarm correlation are as the followings.

(1)Compression: the reduction of multiple occurrences of an alarm into a single alarm.

(2)Count: the substitution of a specified number of occurrences of alarms with a new alarm.

(3)Suppression: inhibiting a low-priority alarm in the presence of a higher-priority alarm.

(4)Boolean: substitution of a set of alarms satisfying a Boolean pattern with a new alarm.

(5)Generalization: reference to an alarm by its superclass. Alarm correlation may be used for fault isolation and diagnosis, selecting corrective actions, proactive maintenance, and trend analysis in the data fusion system.

4.2 Conceptual Framework

One of the major applications of alarm correlation is the fault diagnosis in the data fusion system. Not all faults exhibit alarms. Thus, some faults can be recognized indirectly by correlating available alarms. Correlation between alarms due to a common fault is an equivalence relation.

Alarm generalization is very useful for performance monitoring of the data fusion system. It allows one to deviate from a microscopic perspective of monitoring events of the data fusion system and view situations from a higher level. There are two ways for alarm generalization. The first is subsumption of lower-level alarm classes by a higher-level class. This generalization process may utilize alarm class/subclass hierarchies. The second is interpretation of simultaneous events or events happening within a defined time interval as a qualitatively new complex situation.

The conceptual framework of alarm correlation contains the structural and behavioral components of the data fusion system. The relational approach to monitoring complex system (Snodgrass, 1988) can be used for design and implementation of the conceptual framework. The structural component is the description of the monitored system. It contains two major parts, the configuration model and the element class hierarchy of this system. The configuration model describes the monitored objects, and the connectivity and containment relations between them. The element class hierarchy describes the monitored object types and the class/subclass relationships between the types.

The behavioral component describes the dynamics of alarm correlation. It contains three major components: the alarm message class hierarchy, the correlation class hierarchy, and correlation rules. The monitored object classes, alarm message classes, correlation classes, and correlation rules are organized into hierarchies. These hierarchies are related by producer/consumer" dependencies. Monitored objects are producers of alarm messages, messages produce correlation, and rules are consumers of all the above components.

Monitored classes describe equipment types of the data fusion system. Monitored objects are organized into a hierarchy using class/subclass relations. The root of the hierarchy contains the most general information common to all monitored objects. The next level of the hierarchy describes the basic monitored object classes. Each subclass inherits parameters, values, and attributes. The monitored object hierarchy is an abstraction of physical monitored objects. The hierarchy is specific to the data fusion system.

Configuration model. The configuration model of the data fusion system is constructed from the instances of individual monitored objects. The instances describe the actual physical or logical components of the monitored data fusion system.

Message Class. All alarm messages produced by a specific monitored object are organized into a message class hierarchy using the class/subclass relation. Introduction of message classes simplifies the decision-making process of maintenance of the data fusion system. Each message class in the hierarchy contains a message-parsing pattern and a translation schema, common to a subset of all messages that belong to this class.

Correlation class. A correlation class is a generalized description of status of the data fusion system based on interpretation of events of this system. The conditions under which the correlation is asserted are described in the correlation rules. Each assertion creates an instance of a correlation class. A correlation class contains components, a message template, and parameters. The components may be monitored objects, alarm messages, or other correlations. Correlation components are used to pass information from a correlation rule to the asserted correlation. Parameters provide information about a correlation to higher-level correlations.

Correlation Rules. Correlation rules recognize events and assert correlations. Different correlation rules may assert the same type of correlation. The conditional part of a rule is a Boolean pattern built upon primary terms and relations. The primary terms are messages, monitored

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objects, correlations, and tests. The action part of the rule contains executable commands.

5 PERFORMANCE MONITORING

From the monitoring model hierarchy, the major components of the performance monitoring include monitoring information management, management of monitoring objects, and monitoring policy management. As its name implies, monitoring information management is responsible for organization and recovery from the monitoring information and inflicted damages related to faults in the data fusion system. Management of monitored objects is related to determination of an object position and accommodation of the object distribution changes. Monitoring policy management is responsible for providing the optimally monitoring policy for the performance monitoring by adjusting the performance monitoring decisions, and critical for efficient performance monitoring of complex data fusion system of geo-coded multisensor that is in a dynamic network environment.

One of the key elements of the performance monitoring is how to construct the decision support system of this performance monitoring system. Expert system can be used to support the performance monitoring (Wagenbauer and Nejdl, 1993). In order to effectively monitor the complex data fusion system, the administrator of the system must be able to determine when equipment and facilities within the system are operating in a degraded mode. The administrator must also be able to determine whether they are in normal operation status.

5.1 Basic Model

Modeling the performance of monitored objects is to map distribution, characteristics, and events of the monitored objects to managed objects in monitoring database. An inheritance hierarchy can represent a simple classification of performance object classes, where the elements class has three subclasses: distributions, characteristics, and events. Physical entities class has two subclasses: monitored entities and geographic positions.

5.2 Various Data

Performance monitoring data in the policy hierarchy of the performance monitoring can be broadly classified into the followings.

(1) Measurement data. The measurement data of the data fusion system is the raw information that is received from the monitoring processes, and various data related to the system. The data provides the primary input for performance monitoring. It represents the current status of the data fusion system. Measurement data can be divided into two groups according to the general characteristics of policy of performance monitoring of the data fusion system: persistent and perishable. The persistent data consists of measurement data, whose use is long-term, and therefore needs to be maintained permanently in database. On the other hand, perishable measurement data is of limited time use, so that its current value is valid only until the characteristic of the data fusion system is being monitored.

(2) Structural data. In contrast to measurement data, structural data is composed of static performance information. Unlike measurement data, structural data is valid even when the performance monitoring does not occurs. Most of structural data is stored at initiation time of the performance monitoring system.

(3) Monitoring data. Monitoring data captures the current selection of monitoring decision for the performance monitoring. The process for changing an existing set of monitoring decisions is usually completed by the performance managers of the data fusion system. Alternatively, the changes may be automatically triggered as a function of the information in the measurement data. In addition to the current settings of monitoring decisions, the monitoring database also stores a library of predefined monitoring decision settings that reflect the appropriate settings for a variety of common performance patterns.

Thus, the performance monitoring systems based on policy hierarchy are responsible to monitor and interpret performance of the data fusion system.

5.3 Policy Management

Policy evaluation is used to select optimal policy of the performance monitoring. The role of monitoring policy management of the performance monitoring system is to manipulate the adjustable monitoring policy decisions in real time so that the performance of the data fusion system can be efficiently monitored in order to reduce the loss due to the faults. Monitoring policy management from analysis for policy hierarchy is divided into two task as the followings.

(1) Monitoring policy evaluation that finds how changes in monitoring decisions reduce the fault loss of the data fusion system; and

(2) Decision making on how to adjust the monitoring decisions.

The first task is essentially equivalent to find a relationship between the quality of performance monitoring and the monitoring decisions, and may be required to estimate the quality and loss. The second one is to decide what monitoring decision is selected for the performance monitoring.

5.4 Policy Evaluation

The analytical techniques, such as probability theory, can be used for the monitoring policy evaluation. However, they require unrealistic assumptions and tend to be mathematically untraceable as the structure of the evaluation measure becomes complex. On the other hand, discrete-event simulation is a viable alternative to analytical techniques. Its major advantage is that it can be modeled with much less stringent assumptions, and more complex performance measures can be handled with relative ease. However, discrete-event simulation usually suffers from significant computational burden because a single simulation run represents only one realization of a stochastic process. In order to obtain an accurate estimation of quality of the performance monitoring under a given monitoring policy, several independent runs are needed, and these runs should be repeated.

5.5 Decision Making

In the policy hierarchy, this task requires monitoring decision optimization, and can be accomplished by the learning and inference methods based on expert system.

5.6 Monitoring Forms

Typically, performance management can be divided into monitoring and maintenance aspects. Performance monitoring refers to the collection of information on status of the data fusion system, while maintenance refers to actions taken to improve performance of the system. The performance monitoring system must be flexible enough to satisfy current and future performance monitoring needs regardless of the technology or type of monitored equipment of the data fusion system. The performance monitoring can take different forms as the followings.

(1)One common use is hunting for a specific performance problem in the data fusion system.

(2)Another situation involves global monitoring. The administrator will probably want to be advised of developing problems before they can affect operation of the data fusion system.

(3)A third possible use is the historical analysis of trends and performances of the data fusion system. It may be desirable to be able perform statistical analysis of various performance data over some period of time.

5.7 Monitoring Methods

The most elemental level of the performance monitoring ultimately depends on measuring information about the data fusion system. Measurements may take two forms such as counters and gauges. Counters are cumulative indicators that measure the occurrences of some event or the total number of units of some quantity. Gauges give instantaneous measures of some quantity. A monitored object class of current data is a collection of counters and gauges that are used to monitor the status of the data fusion system. There are different subclasses of current data. Each subclass of current data corresponds to the type of resource being monitored. The subclasses define the particular set of counter and gauges that are applicable to a particular type of resource. Each type of resource being monitored may have a distinct set of counters and gauges that apply only to that type of resource.

Reporting of Scheduled Statistics. The performance monitoring system deals with not only the collection and storage of performance data but also how the data is reported. The system can simply use a command to read the attribute values of the relevant instances of current data, performance event record and history data.

Reporting of threshold Crossings. The performance data is saved at the end of the interval or reported at some scheduled point in time. In many cases, it is desirable to notify the administrator immediately when some event occurs. Monitored objects of threshold data contain the thresholds and related levels associated with the counters and gauges of current data. If a counter or gauge in the current data passes a threshold, a notification is issued. The monitored object instances of current data and monitored object instances of threshold data are related by a relationship. This relationship is used to allow for different ways of using thresholds. Changing the threshold affects the monitoring of many monitored object instances.

5.8 Application

The information of the performance monitoring can be used to complete performance management of the data fusion system. The performance management functionality is broken down into different functional units (Balzer, et al., 1982). Functional units represent sets of capabilities and provide a way for the performance monitoring system and elements of the data fusion system to inform each other of which capabilities they can support. Various functional units are supported by the model. The only additional object classes required for the performance monitoring would be subclasses of current data, threshold data, and possibly an event forwarding discriminator.

In this scenario, the monitored object instances of current data will be created by the elements. For each of the resource, such as components being monitored, the element would instantiate an appropriate monitored object of current data. The instance of current data would be contained within the monitored object representing the resource. The elements select the options such as the performance summary interval and set of counters and gauges. The current data object instances would point to one or more threshold data objects that define the conditions causing the spontaneous performance reports to be issued.

6 MONITORING IMPLEMENTATION

With our approach to solve the above problems of performance monitoring, information distribution strategy and automatic/adaptive monitoring are to incorporate learning and inference abilities into the performance monitoring system to automate the process of global view construction, measurement interpretation, problem forecasting, problem diagnosis, and decision making related to the performance monitoring.

6.1 Global View

To build the information infrastructure about the performance monitoring, a set of global views is constructed with the help of the above policy hierarchy. A global view is a virtual object class defined from monitoring information base (MIB) via logical rules. From the relationship between making policies, these global views serve as windows through which monitoring applications can access physical entities about the performance monitoring.

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To implement the above automatic and adaptive abilities, the performance patterns related to policy attributes must be learned from a historical database which contains a chronological measurement trace. These discovered patterns have been represented and describe the correlation between monitored objects of the data fusion system. Based on these performance patterns and prespecified domain knowledge, forward and backward inference can be triggered to access global views, predict performance status, fire maintenance actions, and reported problems. In our abstract decision process model of the performance monitoring system of the system, the extensional database(ED) is used to represent the basic facts about distribution, severity and alarms, and events of the system faults. Each fault has an associated ED which is its view about the fault. The historical database(HD) is the temporal historical database which encodes time in the fault trace. Performance patterns are learned from HD and stored in Pattern knowledge Base(PKB). The domain knowledge base(DKB) is for prespecified problem solving and general relationship knowledge.

6.2 Reasoning Process

Each performance pattern is represented as a logical rule in PKB, and describes a correlation between the attributes of objects of the system faults and related policies. These correlations come from HD, where selected attributes are logged according to the specific monitoring policy. If the status of the fault objects satisfies the body part in the rule, the pattern from past experience represents that it is very likely that the status of the fault object also satisfies head port with some probability. A logical rule has the generic form: IF X THEN Y, where X is its body part and Y is its head part. If some undesired status of a disaster object is foreseen to occur, it can further fire some logical rules in DKB and then trigger preventive maintenance actions for the possible system faults.

6.3 Events

Monitored object can be defined not only as a representation of a monitored resource but also as part of the performance monitoring system. The status of an object is a measure of its behavior at a discrete point in time and is represented by the current values of a set of status variables contained within a status vector. An event is an atomic entity that reflects a change in the status of an object. The status of an object has a duration in time; an event occurs instantaneously. Three kinds of events are of interest in the data fusion system as the followings.

(1) A maintenance-flow event represents a maintenance activity and is associated with a maintenance thread.
(2) A data-flow event occurs when a status variable is changed or accessed.
(3) Process-level events show the creation and deletion of processes. They describe the interactions and data flow between processes.

6.4 Interfaces

The interface of a monitored object can be divided into two part as the followings.

(1)An operational interface supports the normal information processing operations, fulfilling the main purpose of the service provided by the object.
(2)A management interface supports the performance monitoring and maintenance interactions in the data fusion system.

6.5 Information Generation

Monitoring information is generated by object instrumentation, where software, hardware and hybrid probes or sensors detect events or generate status and event reports. A sequence of such reports is used to generate a monitoring trace.

Status Reporting. Status reports contain subsets of values from the status vectors and may include other related information such as time stamps and object identities in the data fusion system. Status reporting criteria define which reporting scheme to use, what the sampling period is, and the contents of each report.

Event Detection and Reporting. The detection of an event may be internal. A function is used to update the status vector and to check the event-detection criteria. An external agent can perform event detection. The agent receives status reports and detects changes in the status of the object. Once an event is detected, a report is generated that contain information such as the event identifier, type, priority, time of occurrence, and the status of the object before and after the event. Event reports may also contain values of other application-specific status variables.

Trace Generation. To describe the dynamic behavior of an object or a group of objects over a period of time, event and status reports are recorded in time order as monitoring traces. Such traces may be used for postmortem analysis. There are two kinds of traces. A complete trace contains all the monitoring reports generated by the system since the beginning of the monitoring session. A segmented trace is a sequence of reports collected during a period of time.

6.6 Information Processing

After monitoring information is generated, it must be processed. A monitoring service provides various functional units as the followings. These units can be combined in different ways to suit the monitoring requirements.

Trace Processing. Monitoring traces may be constructed and ordered in various ways to provide different logical views of activity of the data fusion system over a period of time. The selection criteria in determining how monitoring traces are processed are in the followings.

(1)Generation, arrival time stamp, and other features of report.
(2)Identity, priority, and other features of reporting entity.
(3)Identity and type of the monitored object to which the report refers.

Information Validation. Performing validation and plausibility tests on monitoring information to make sure that the data fusion system has been monitored correctly

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is another important monitoring activity. Validation is performed according to certain validation rules.

Database Updating. Valid monitoring information is used to maintain and update a representation of the current status of the data fusion system in monitoring data base. A conceptual database model of the system is constructed and continuously updated to represent the current status of the system. There are two general approaches to collecting the data for database updating/as the followings.

(1)Dynamic approach: user queries result in the automatic operation of relevant sensors in monitored objects, which collect the required data.

(2)Static approach: All possible monitoring data is to be collected and stored for potential access by users. The collection of data is independent of its use.

Information Combination. The combination is to increase the level of abstraction of monitoring data. With the help of the process, managers can observe the behavior of the data fusion system at a desired level of detail. Thus, low-level primitive events and states are processed and interpreted to give a higher-level view of complex status and events.

Filtering and analysis. The performance monitoring systems may produce thousands of alarms per day, making the task of the real-time performance surveillance and system maintenance difficult. Due to the large volume of alarms, the system manager frequently overlook or misinterpret them. To reduce the number of alarms displayed on manager' terminal, the performance monitoring system of the data fusion system applies alarm filtering procedures. On the other hand, the monitoring system generates large amounts of monitoring information. This results in heavy wage of computation resources. Filtering is the process of minimizing the amount of monitoring data so that managers only receive desired data at a suitable level of detail.

6.7 Dissemination and Presentation

Monitoring reports generated by objects are forwarded to different users of such information, including human users, managers, other monitoring objects and processing entities. Several presentation techniques based on ArcView 2.1 (ESRI, 1994) can be used in the performance monitoring system to display configuration, performance and other information.

7 CONCLUSIONS

One of effective methods for solving the problem of the performance monitoring of complex data fusion system of geo-coded multisensor in network environment is to look into a new theory and related method for designing a framework for implementing the performance monitoring system. Thus, the above approach to monitoring the data fusion system is developed to study the principle and application of the monitoring model to design and implement the performance monitoring system. The monitoring model concept and its definition are two keys to design and implement the monitoring system. Research results for the model indicate that this new approach has also many other advantages such as simple model construction process, easy correctness verification, management and maintenance, and easy integration with other software packages such as expert system, machine learning systems, large database systems and special simulation systems. A prototype system has been used to analyze and process a number of field data. The final experiment results from the system show that this model has very satisfactory performance and fast operation speed with comparison of traditional methods. Several improvements are possible. For example, the approach to monitoring the data fusion system can be used in conjunction with a Geographic Information System (GIS) in developing the initial monitoring model. GIS is a promising tool for building the monitoring system. The major difficulty lies with creating a good architecture for the model implementation.

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