The Method of Different-type Data Fusion for Nuclear Monitoring

SHEN Qiang, HUANG Li, LI Shi-yi

***Abstract*—Based on the network of nuclear monitoring by multi-sensor and many means, the method of multi-sensor and different-type data fusion is studied. The architecture, the construction and the detail algorithm are introduced in emphasis. This paper can be used for reference about the algorithm and software of nuclear monitoring data center.**

***Index Terms*—nuclear monitoring, algorithm, multi-sensor and different-type, network**

I. INTRODUCTION

Because of the long distance of the detection workstations and explosions, and the similarity of nuclear events and other manmade or nature events, the signals of nuclear events will be easily submerged in the background with strong noise in monitoring of nuclear events. Operated by one workstation or method, the precision of nuclear event location and parameter calculations will reduce, and the rate of false alarm and missing report will arise. Generally speaking, International Monitoring System (IMS) consists of multi-workstation, multi-sensor and multi-method of seismic, infrasonic, hydroacoustic and radionuclide. Because of the heterogeneities of the data collected by different methods with different principles and eigenvector dimensions, the data fusion of IMS is the multi-sensor and multi-type data fusion. The fusion system, architecture of system and algorithm of fusion can borrow ideas from the classic theory and algorithm of data fusion, also some key problems in technology need to be solved for the particulars.

II. ARCHITECTURE OF MULTI-SENSOR AND MULTI-TYPE DATA FUSION

The essence of multi-sensor and multi-type data fusion is to fuse the primitive data collected from different time-domain and frequency-domain in order to calculate the parameters of nuclear events more accurately. Fig 1 shows the three architectures of the multi-sensor and multi-type data fusion, which are the core-level fusion based on primitive data, the core-level fusion based on eigenvector dimension, and self-organization [1,2].

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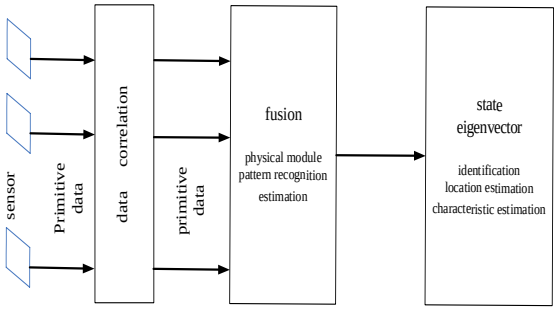
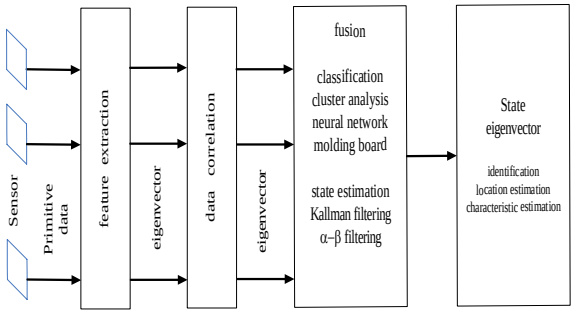
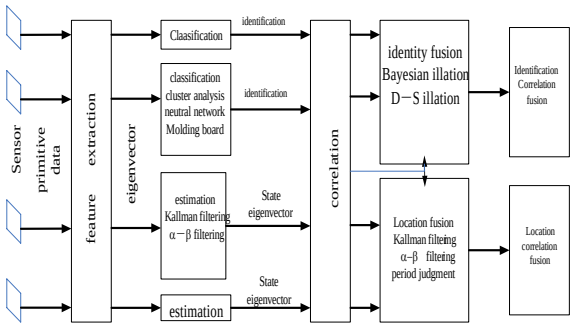


(a) The fusion system of core-level fusion based on primitive data



(b) The fusion system of core-level fusion based on feature extraction



(c) The fusion system of self-organization

Fig 1 Three basic architectures of multi-sensor and multi-type data fusion

The core-level fusion based on primitive data means that the primitive data enter the fusion function module directly after correlation, and then processed by physical module, the method of pattern recognition and estimation technology.

The core-level fusion based on feature extraction means to extract the features of the data measured by the sensors before correlated, in order to get the eigenvector. In the fusion function module, classification, cluster analysis, neural network, molding board, state estimation, Kallman filtering and $\alpha-\beta$ filter are used.

The self-organization classes and estimates the objective events after features extracted, so the process of correlating data are operated in the layer of state eigenvector and identity estimation. Among these, location fusion can confirm whether the objective event exists or not, and correlate all the sensors data to an objective event, then the location can be got from a set of correlated characteristic quantities. Identity fusion correlates to location fusion, but the purpose is to confirm the identities and attribute features of the objective event.

III. CONSTITUTION OF MULTI-SENSOR AND DIFFERENT-TYPE DATA FUSION SYSTEM

Fig 2 shows the system constitution of Multi-sensor and multi-type data fusion. In Fig 2, the ellipses represent four kinds of monitoring methods, every method is made up of several workstations scattered over a definite area, and every workstation is generally made up of an "array" formed by several same types of monitor sensors in an area. In every detection workstation, there is a preprocessing center in which signal preprocessing, primitive location of nuclear events and parameter estimation are operated.

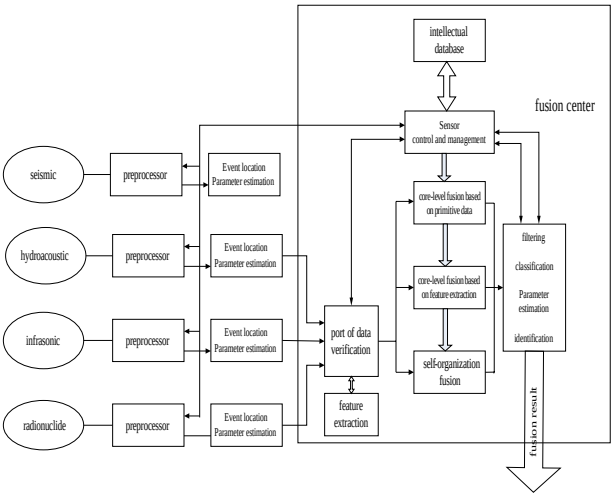


Fig 2 Constitution of Multi-sensor and Different-type data fusion system

The fusion center is made up of data verification port module, features extracting module, intellectual database module, sensor control and management module, primitive data core-level fusion module, characteristic data core-level fusion module, self-organization fusion module, and other modules of filtering, classing, parameter estimation and identification. The characteristic extracting module extracts the characteristic parameters of the nuclear events and the data collected by all kinds of methods, providing the source data to core-level fusion based on characteristic parameter. The intellectual database stores the norm of fusion and the apriori knowledge such as the characteristic parameters of previous nuclear events, supporting fusion illation and parameter estimation. The sensor control and management module controls the data collected and transmitted in the workstations, passing in and out of the intellectual database, and also selects the methods of fusion. In the International Monitoring System, the architecture of data fusion in one level is different from it in another level. In the workstation, the data is collected by sensors with the architecture of core-level fusion based on primitive data, in one monitoring method the data collected and preprocessed will be fused with the architecture of core-level fusion based on eigenvector dimension, and data fusion between the different methods with the architecture of self-organization.

IV. ALGORITHM OF MULTI-SENSOR AND MULTI-TYPE DATA FUSION

There are two kinds of algorithms of multi-sensor and multi-type data fusion, one is detection–classification -identification, judging characteristics and identification of events. The other is parameter estimation and location, calculating the parameters of location and valent weight of nuclear events [3].

A. Algorithm of detection-classification-identification

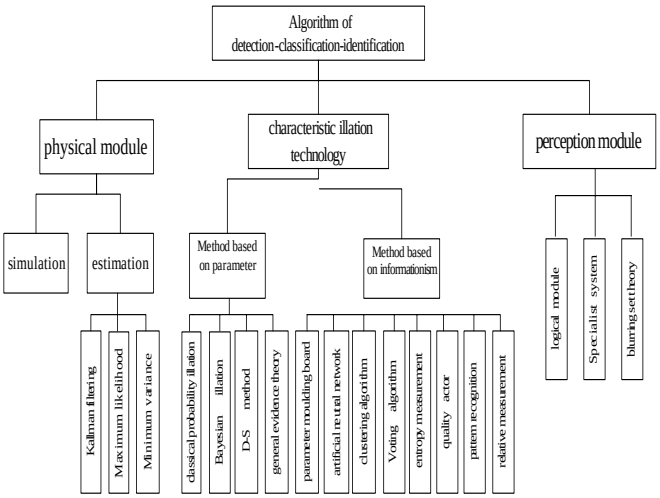


Fig 3 Algorithm of detection-classification-identification

Fig 3 shows the algorithm of detection-classification -identification, including the algorithms based on physics module, characteristic illation technology and perception module.

Physics module shows some characteristics of judgment, such as the explosion weight correlates to the intensity of seismic, hydroacoustic, infrasound and radionuclide waves of nuclear detection. The classification based on physics module and the algorithm of identification can be realized by matching the actual data observed and all kinds of physics modules or the signals of events stored before. The illation technology based on characteristic can be realized by mapping the data including the statistic information and characteristic data of nuclear events to identification space. The illation technology based on characteristic can be divided into the method based on parameter and the method based on technology of informationism theory. The method based on data maps the data directly into identification space, and the specific methods of it include classical probability illation, Bayesian illation, D-S method and general evidence

theory. The method based on technology of informationism theory can transform or map the data into identification space. In identification, the similarity can be showed by the similarity of the parameters in the observation space, but it is forbidden to set up the identification function of some aspects of observation data. There are some specific methods including parameter moulding board matching, method of artificial neutral network, clustering algorithm, voting algorithm, technology of entropy measurement, quality actor, and the technology of pattern recognition and other relative measurement. The perception module consists of logical module, system based on knowledge and blurring set theory. The perception module tries to make a strategic decision automatically by simulating the process of human.

B. Algorithm of parameter estimation and location of the goal events

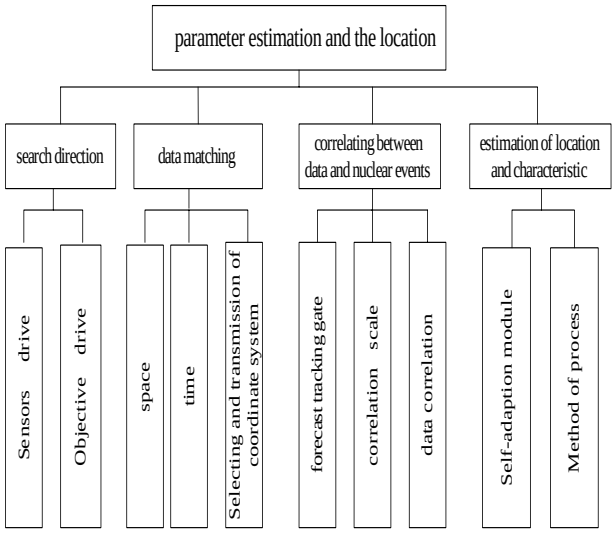


Fig 4 Algorithm of parameter estimation and location of the goal events

Fig 4 shows the algorithm of parameter estimation and the location. The algorithm of state estimation and location in the top level consists of the two parts following: confirming search direction and correlating the data measured. The process of correlating goes on to be divided into three parts, including data matching, correlating between data and nuclear events, and estimation of location and characteristic. The search direction can be driven by the sensors or the objective. In the sensor system, the initialized objective report forms including the radial distance and azimuth will be correlated to the report form data. In the objective driving system, one workstation will be used to track, and the location detected by the workstation will be used to guide the other workstations to get the report form data, or to search the database to find the most matching report form data to the objective location. The purpose of data matching is processing all the monitoring data in a general reference system of axes. The correlation between data and objective events includes setting up forecast tracking gate, defining the correlation between relative dimension and practical data. The purpose of setting up forecast tracking gate is dividing the data into two types, one is updating the parameters of old nuclear events, and the other is initializing the parameter of new nuclear events. The size of tracking gate means the difference of calculation and prediction of the event location, which correlates the calculation method with the differences in the sensors and the correct correlation probability.

V. KEY TECHNOLOGY AND SOLUTION OF MULTI-SENSOR AND MULTI-TYPE DATA FUSION

The information detected by the methods of seismic, infrasonic, hydroacoustic and radionuclide, are heterogeneous, show some characteristics such as asynchronous and nonholomic. The specific performances are followings: asynchronous in time and space, various data rate, mismatching of data dimension, disunity of information formulation, increasing of information and the types with the time. The solution is to standardize data form and data matching. The data will be correlated in a time-space reference system of axes by adjusting the old time-space reference system and selecting and transforming the system of axes. The correlation of data is a process of statistical decision, which can be used to seek out the uncorrelated information of nuclear events collected by any methods of detection, only fuse the data originated from one nuclear event with the technology of various decisions illation rule. In the process of data fusion in IMS, the decision and rule should be adjusted and deducted according to the characteristics of detection data colleted by different methods in different times, because the data colleted by different methods comes to the fusion center one after another.

VI. CONCLUSION AND SUGGESTION

This paper specifically introduces the system, constitution and fusion method of multi-sensor and multi-type data fusion, the key technology and solution of it. In the following period of time, a feasible algorithm of data fusion will be investigated directly towards the specific characteristics of seismic, infrasonic, hydroacoustic and radionuclide wave, in order to get a new method which is superior to the single detection method.

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