Research of Intelligent Fault Diagnosis Model on Multi-Information Fusion

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***Abstract*—From the intelligent fault diagnosis system requirements, this article analyzes the relationship between the fault diagnosis and the multi-information fusion basing on the summing up the multi-sensor information fusion technology, and studies the hierarchical structure of multi-sensor information fusion system and the content of integration, and establishes an intelligent fault diagnosis model with the multi-information fusion, which provides strong support for large-scale equipments, system monitoring and fault diagnosis in production process.**

***Index Terms*—intelligent fault diagnosis, multi-information fusion, multi-sensor, intelligent model**

I. Introduction

With the development of modern science technology and industry production, various equipment increasingly large-scale and precision, resulting in the probability of fault occurrence increasing obviously, fault orientation, analysis and eliminate are also more difficult, the single information collection or more information will be simple processed exist the unsatisfactory place, so as to more information fusion processing, in order to improve the veracity and reliability of fault location. In addition, when the fault occurs, the first inference of people or experts is also the important information sources. However, this information source is usually overlooked because it is not easily quantified or it is not precise. After the information fusion technology has emerged, it provides a powerful tool for solving these problems, and opens a broad prospect fault for fault diagnosis development and application. The information fusion can use the collected information and artificial experience to predict scientific comprehensive treatment, in order to improve the intelligence degree of state detecting and fault diagnosis.

Intelligent fault diagnosis mainly includes three aspects: fault detection, data pre-processing and fault diagnosis. The so-called fault detection is to judge whether the system is faulty and the fault found out time; The data pre-processing is to properly processed the collected data and extract the characteristics of fault in preparation for the following-up diagnostic analysis; Fault diagnosis is the use of fault diagnosis theory to reason out the type and severity of faults.

More complete definition of information fusion: A multi-level, multifaceted process, this process is to detect multi-source data, combine, relevant, estimate and combine to reach the accurate state estimates and indentity estimates, as well as complete and timely situation assessment and threat assessment [1-2]. In recent years, the basic theory and implementation methods of information fusion technology have been greatly improved, which showed its great advantages, mainly in tolerance, high system accuracy, faster information processing speed, highly complementary, lower cost to get information, etc.

Currently information fusion is mainly used in target detection, identification and classification, control decision-making generation, signal transformation, integration, filtering, and synthesis, system diagnosis and other fields. Multi-sensor data fusion technology has been developing with different applications and the object development. The technology has been applied to the fault diagnosis in the last few years. The traditional fault diagnosis method is mostly based on a single detection data processing, and under the situation of thinking of only one information, to diagnose according to the calculation result and simple causal reasoning, the results must be one-sided. Also the missed diagnosis is inevitable owing to detecting only by single fault diagnosis information. This paper analyzes the relationship between fault diagnosis and multi-information fusion, studies the hierarchical structure of multi-sensor information fusion system and the integration content, and establishes an intelligent fault diagnosis model based on the multi-information fusion.

II. Multi-Sensor Information Fusion Technology Overview

The basic principle and the starting point of information fusion are: Making full use of multiple information sources, and according to them and provided information are reasonable dominated and used, the redundancy or complementary information of multiple sources in space or time are composed by the certain standard, so as to obtained the consistency explain or described of the tested object, thus the information system obtain more superior performance than the subset system is constructed by each component. The multiple sensor information fusion technology is applied to fault diagnosis system, which can enhance the accuracy of the system fault diagnosis, and to a certain extent, obtain precise state estimation, which can improve the detection performance, increase the confidence of the diagnosis result. At the same time, it makes full use of

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sensor resource, maximum playing scheduling system and improving the information resource utilization.

In recent years, multi-sensor information fusion technology is received widespread attention in military field or in civil fields [3-5]. This technology is widely using in automatic target recognition, battlefield surveillance, automatic vehicle navigation, robots, remote sensing, medical diagnosis, image processing, pattern recognition and complex industry process control, etc. Multiple sensor data fusion is that the data is collected by different knowledge sources and sensors are fused, in order to achieve a better understanding for object of observation. On the surface, the concept of multiple sensor fusion is very straightforward, but in fact really achieving a multiple sensor fusion system is difficult. Heterogeneous sensor data modeling, collaborative and interpretation are challenging job. Although there are many difficulties, but due to multiple sensor fusion system has the huge potential to improve system performance, people still spent a lot of energy to research.

Figure 1 is the multi-sensor data fusion diagram. The sensor redundancy data has enhanced the system reliability and the sensor complementation data has expanded the individual performance.

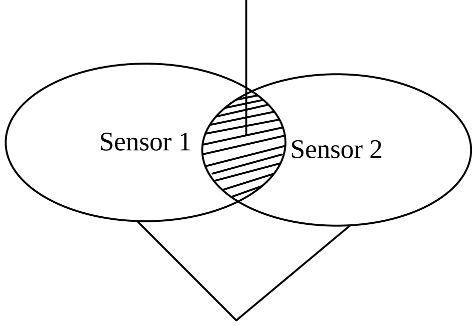

Fig. 1. Multi-sensor data fusion diagram

Generally speaking, multi-sensor data fusion system has the following advantages:

a) Improving the system reliability and robustness.

b) Expanding the observations scope in time and space.

c) Enhancing data's credibility.

d) Enhancing the system distinguishing ability.

Designing multi-sensor data fusion system should consider the following basic questions:

a) Type, resolution, accuracy of the sensors in system.

b) Distribution form of the sensors.

c) Systemic communication ability and computing power.

d) Systemic design goal.

e) Systemic topological structure (including data fusion levels and communication structure).

III. THE MULTI- INFORMATION FUSION MODEL

Based on the concept of multi-sensor information fusion, The key problem of information fusion is model design and integration algorithm [12]. Information fusion model includes functional model, structural model and a mathematical model.

a) Starting from the fusion process, the function model describes that information fusion includes main functions and database, and the interaction between the various components of the system.

b) Starting from the composition of information fusion, structural model explains software and hardware components of information fusion system, data flow, man-machine interface of systems and external environment. It has a variety of different classification methods. One classification is based on the degree of processing of sensor data before it be sent into fusion center. In this classification standard, fusion structure is divided into sensor-level data fusion, central-level data fusion and hybrid fusion. You can also classify to the fusion structure according to the resolution of data process. In this case, fusion structure is pixel level, feature level and decision level fusion.

c) Mathematical model is information fusion algorithms and integrated logic, Algorithm mainly Includes distributed detection, spatial integration, attribute fusion, situation assessment and threat assessment etc. Multi-sensor information fusion to achieve a mathematical model of information fusion method involves many theories and techniques, Such as signal processing, estimation theory, uncertainty theory, pattern recognition, optimization techniques, fuzzy and neural network. This research has been done at home and abroad. Currently, these methods were roughly divided into randomly class methods and artificial intelligence methods.

The general functional model of information fusion has important significance for the design of integrated systems structure and effective use of multi-sensor information. Luo and others have proposed hierarchical fusion structure, demonstrates the fusion problems by multi-sensor information distributing in the same geographical region, point out that the hierarchical structure of integration can largely reduce the requiring data storage capacity for each stage in the recognition process and the required communication bandwidth connected with information (data) in different platforms. Thomopoulos and others also brings forward the method about classification hierarchy for multi-sensor information fusion.

Many scholars have put forward a general function model of information fusion system from different angles, trying to characterize multi-sensor fusion technology from the function and structure. The most authoritative functional model brought forward by the DFS (American military organization---laboratory director joint(JDL).The following function model was brought forward by C^3I Technology Committee (TPC^3) data fusion expert group, ts simplified model shown in Figure2:

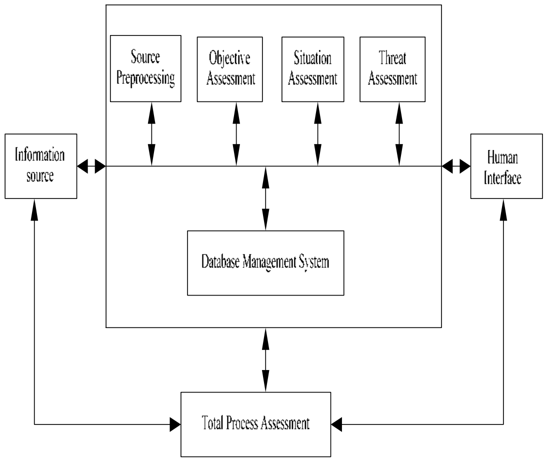

Fig. 2. The multi-sensor information fusion model

The basic functions of this model of each module are as followings:

a) Information Source: including the sensor and its relevant data (such as databases and prior knowledge of people and so on).

b) Source Preprocessing: data pre-filtering and data distribution, which can reduce the computational burden of fusion centers, sometimes it needs to provide the most important data for the fusion center.

c) Objective Evaluation: the evaluation of fusion target position, speed, status and other parameters can accurately express these parameters. It mainly Includes data registration, tracking, data association and identification.

d) Situation Assessment: According to the current testing environment to infer the relationship between detecting goals and events in order to judge the intention of detecting targets.

e) Threat Assessment: With the present situation to judge the threat of enemy attacks on both the extent and ability of the enemy. This process should also take into account the current political environment and enemy tactics and other factors, it is more difficult.

f) Total Process Assessment: monitoring system performance, identifying and improving the requiring data performance, rationally allocating sensor resources.

g) Human Interface: providing the interaction functions between man and computer, such as artificial operator's guidance and evaluation, multimedia functions, and so on.

h) Database Management Systems: the main functions are system data storage, retrieval, compression and protection.

IV. THE RELATIONSHIP BETWEEN FAULT DIAGNOSIS AND THE MULTI-INFORMATION FUSION

In essence, the fault diagnosis system is to process the comprehensive information by using a variety of diagnostic target system operation status information and existing range of knowledge. Finally, the comprehensive evaluation will be got about the system operation state and fault condition. Definition of multi-information fusion can be summarized as: detecting a variety of physical quantities of systems in many aspects using multiple sensors. The information of multiple sources and data can be processed by classification in order to determine the state of the system accurately and timely, to get correct judge about system fault or fault model, and to analyze the relationship among the state (fault), phenomena (symptoms) and the reasons [6]. Thus it can be seen, both have the same purpose and requirements.

A. The Multi-Information Fusion Hierarchy Structure of Suitable Fault Diagnosis

For multiple sensor fusion hierarchical questions, people exists different views.Luosen Lin [7] divided the common system structure into detection level, temporal level, attribute level, symbol level. Wen-Xian Yu [8] divided the level of information fusion into the data level, feature level and decision level, He extended DFS's functional model to the more general case, shown in Figure3:

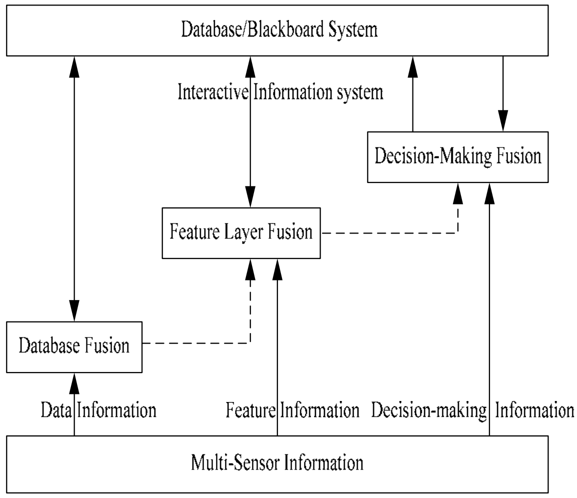

Fig. 3. Multi-Information Fusion Hierarchy Structure

a) Database Fusion: Analyzing and processing multi-rate sensor information, fusing and estimating system's status and parameters, getting the characteristic parameters required in diagnosis. Data level fusion can be done by data to data or data to feature. Shown in Fig.4(a):

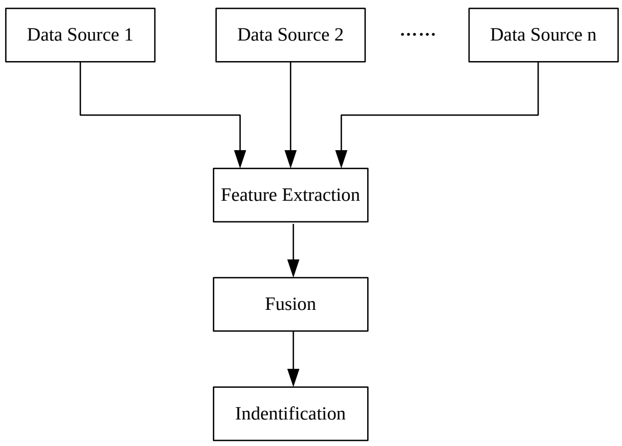

Fig. 4 (a). Data layer fusion

Data layer fusion is that data is observed by all of sensors is first fused, then extracting feature vector from the fusion data, and judging identification. This shall request sensor is coessential (cross-correlated sensor is the same physical phenomenon). If multiple sensors are heterogeneous (observation is not the same physical quantities), then the data is fused only in the feature layer or decision-making layer. Data layer fusion does not exist data leak problems, and obtaining result is also the most accurate, but communication bandwidth demanding is very high for the system.

b) Feature Layer Fusion: Using the signal processing technology, it can analyze the fusion's result from data level, complete the extraction of characteristic and carry on fusion processing with other relevant characteristic information, obtain required recognition characteristic, in order to realize the effective decision-making for the fault.
Shown in Figure 4(b):

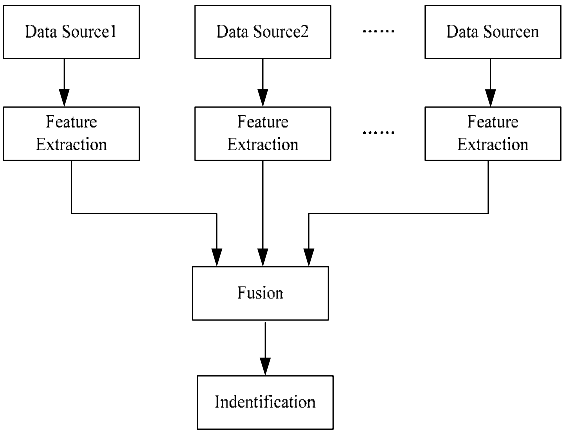

Fig. 4 (b). Feature layer fusion

This kind of fusion method is that the typical features are extracted by each sensor from observation data, and are fused into a single feature vector, then apply pattern recognition method to process. This method requirement is relatively lower for communication bandwidth, but due to data loss to lead to the accuracy decline.

c) Decision level fusion is that the target is identified by each sensors, the multiple sensor recognized results are fused, due to sensor data is concentrated, this method generates the result to be relatively inaccurate, but its requirement is relatively lower for communication bandwidth. Multiple sensor fusion system certain of engineering application should be taken into account the sensor performance, the system computing power, communication bandwidth, expectations of accuracy and funds, so as to determine which level is optimal. Moreover, in a system, it may also be fused in the same time in different fusion layers. Shown in Figure 4(C):

In addition to the above three layers fusion structure, there also are a few kinds of following fusion hierarchical categorization method:

a) Four layers structure mode: Signal level fusion, Pixel level fusion, Feature level fusion and Symbols level fusion.

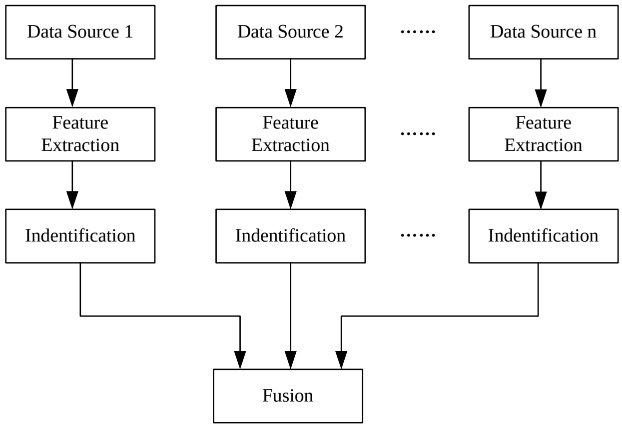

Fig.4 (c). Decision –making fusion

b) Input/output data types classify mode: Data input - data output fusion, Feature input - feature output fusion, Decision input - decision output fusion, Data input - feature output fusion, Feature input - decision output fusion, Data input - decision output fusion.

From the layer structure, for the fault monitoring, alarming and diagnosis system, figure 2 shows proper structure. The functions of the three layer structures can be used for the monitoring alarming of fault diagnosis system, diagnosing fault, and separating fault for different layer requirements.

B. Information Fusion Content of Suitable Fault Diagnosis

From fusion content, Zu Xu Tan[11] divides information fusion into data fusion and rule fusion according to different fusion target. In the practical processing, the two aspects exist, usually coming from sensor data pre-fusion processing. That is: carrying on data fusion, then to reason for the fused information and the information(or data) coming from other aspects according to the rules. On some occasions, perhaps they come from sensor data directly takes part in rules fusion, and perhaps data fusion does alternately with rules fusion.

Data fusion is to process the obtained data according to the requirement, and to get the needed new data. But the appearing new problem while solving data fusion is how to use the large amount of data to discover potential and unknown new knowledge, as well as to revise the original knowledge mastered by the experts according to the existing operation state in order to monitor faults, alarm and diagnosis much faster and more completely! These belong to data collection and knowledge fusion problems.

For the fault diagnosis system, they have to include data fusion, also include knowledge fusion (including the rules fusion, model fusion, etc.), but also includes the fusion from the data to knowledge (data mining).In the actual information fusion system, the multi-sensor data is firstly fused, then the fused data and the information from the object ontology and other information (rules knowledge, model knowledge, etc.) are reasoned according to certain rules, that is, knowledge fusion. At the same time, store the information to database systems, use data mining techniques, reserve the necessary data for knowledge discovery.

V. MULTI-SENSOR DATA FUSION FAULT DIAGNOSIS PRINCIPLE

A.. Object State and Multi-Sensor Perception

When the object operates, n detected points state is mathematics discribed as:

$$R(t) = [r1(t), r2(t),......, \ rn(t)]^T,$$

Where, there is not the cause-and-effect correlation between $ri(t)$ and $rj(t)$. They are independent, and these state components are sensor measurable. $r1(t), r2(t),......, rn(t)$ express quantitative physics meaning to be different, and using the dimension is also inconformity, thus single sensor impossible to measure these quantities. It needs to use multiple sensor measurements. n sensors measure $r1(t), r2(t),......, rn(t)$, and the measured value and being measured values are the one-to-one mapping:

$$G(t) = [g1(t), g2(t),.....gn(t)]^T: \quad R(t) \leftrightarrow S(t),$$

The measurement values are obtained by n sensors:

$S(t) = [s1(t), s2(t),.....sn(t)]^T$, and $si(t) = gi(ri(t))$.

$gi(\bullet)$ is the input/output feature function of the sensor Si . It is a mapping function, and is decided by the sensor.

B .Feature Extraction

Generally speaking, when the object normally works, its observation point will be a relatively stable state. Feature extraction function is that judging data is collected by the sensor is normal or not, so as to judge object is normal or not. Judging rules as follow:

$$Ti[Ii(t), Ci(t)] \rightarrow Di(t), \qquad (1)$$

Where, $Ti(\bullet)$ is rule that judging the sensor i data is normal or not, $Ti(t)$ is data that it is pretreated by the sensor i . If does not distinguish, it can be considered as: $Ii(t) = si(t)$. $Ci(t)$ is the judgment standard that the sensor i data is normal or not. The simplest situation is a constant (or constant vector). $Di(t)$ is the judgment rules output. It generally is binary $\{0,1\}$, or is also available values in among $[0,1]$. This system uses before a method. It is expressed as:

$$Di(t) = \begin{cases} 0 & (the \quad sensor \quad i \quad data \quad is \quad normal) \\ 1 & (the \quad sensor \quad i \quad data \quad is \quad not \quad normal) \end{cases}$$

Therefore, as long as defined the good $Ti(\bullet)$ and $Ci(t)$, it can realize fault feature extraction. When using computer to achieve formula (1), each sensor $Ti(\bullet)$ and $Ci(t)$ can be stored in database (or an array), then programs read from the database, and according to the predetermined rules explain $Ti(\bullet)$ and $Ci(t)$, so as to achieve the judgment calculation that the sensor data is normal or not. This method advantages are: Firstly, when adding, deleting or change a sensor, we change the $Ti(\bullet)$ and $Ci(t)$ in the database, without changing the program itself. Second, when tested object change and sensor has not been changed, changing database (or basically do not make any changes) can achieve judgment rules (formula (1)).

C. Fault Diagnosis Unit

Fault diagnosis unit is that when its corresponding data is not normal, determine the object (including sensor) possible to generate fault unit. In order to make full use of the real-time data is collected by multiple sensors, the fault diagnosis rules are provided as following:

$$Ei = \{ei1, ei2,....eiki\}(Di(t) = 1);$$

$$Mi[Ii(i)] \rightarrow Qi = \{qi1, qi2,....qiki\},$$

Where, the first formula express that when sensor isn't normal ($Di(t) = 1$), it may generate all fault unit. Ei according to experience or the object theory analysis to determine. $Mi(\bullet)$ according to sensor data calculate all elements of Ei . In other words, the fault unit may generate probability $Qi(\bullet)$. $Mi(\bullet)$ get probabilistic functions of $Ii(\bullet)$ corresponding to the various elements in Ei . At last, $Qi(\bullet)$ will be normalized.

D. Decision Fusion

Decision fusion unit is that the data is exported by sensor fault diagnosis unit is fused, so as to determine object whether generating fault or not, and after fault occur, who is the most likely fault unit. In fact, Data fusion is the decision level fusion right now. A common method of decision fusion is the voting method. This paper research uses the improved voting decision method.

$$f3 = \sum ni = 1qi3 \qquad (2)$$

Where, $qi3$ express the probability that sensor fault diagnosis unit output and fault unit are $e3$.

Therefore, $f3$ is the probabilistic sum of fault unit $e3$.

Let $m3$ is the total (total votes) of i when $qi3 > 0$. All of the fault units are operated by formula (2), and the total probabilities $f3$ and total votes $m3$ are multiplied to obtain as follows:

$$F = \{f1m1, f2m2,....fkmk\}$$

Let : $f\max = \max\{F\} = fjmj = \sum ni = 1qijmj \qquad (3)$

If : $f\max > fthrd, \qquad (4)$

Then object malfunction, and fault unit is qij in formula (3) corresponding fault unit ej . $fthrd$ in formula (4) is the threshold based on the probability of voting decisions.

VI. INTELLIGENT FAULT DIAGNOSIS MODEL ON MULTI-INFORMATION FUSION

From the standpoint of intelligent fault diagnosis system , there are a large number researches, they are respectively concentrated in two aspects of the diagnostic methods of closely combining diagnosis object and the general diagnosis method of universal meaning. From the view of the information fusion to know these two aspects research, they are respectively corresponding to the content of data fusion and knowledge integration. No matter from organic connections of fusion content or operation history of fusion system, data mining technology should be regarded as the necessary component parts in the information fusion system. Data mining is also called the knowledge discovery in the database. It is a process of extracting the hidden, previously unknown and potential useful information from a database. The quarried knowledge can be applied to information management, query processing, decision support, process control, and many other applications. Data mining need find the typical knowledge includes relevant rules, classification rules, clumping rules and sequence modes, etc. Based on the relationship problem of fault diagnosis and information fusion, fault diagnosis and information fusion technology have been organic united, so as to establish a intelligent fault diagnosis system model of more information fusion.

A. Confirm the Diagnosis Object

The physical objects Including the controller, sensor systems, are not only sources of information, but also the object eventually to monitor alarm, fault diagnosis and fault isolation measures.

Diagnosed object is not only the source of information but also the basis of information fusion. Physical objects may be continuous or discrete system, may be linear or nonlinear systems, may be steady or time-varying system, may be deterministic or stochastic systems. The information from the object may be digital or analog, may be sound, image or text, its interference has different statistical properties.

Diagnostic systems are able to master and use the knowledge on the diagnosis object is a necessary prerequisite for diagnosis. From the perspective of fault diagnosis, the description methods of the diagnosis object are various. Mathematical models include system state equations, transfer function, etc. Function models include graph theory, influence matrix method, Petri network methods, etc, Reliability models include reliability block diagram, fault tree and so on. In addition, there are more general emotional knowledge, such as fault plans of diagnosis object, rules knowledge, etc.

Basing on the above recognition for fault diagnosis object, this paper corresponds the information fusion layer and fault diagnosis function and brings forward the intelligent fault diagnosis model for multi-information fusion, shown in figure 5:

B. Information Fusion and Fault Detecting on Detecting Level

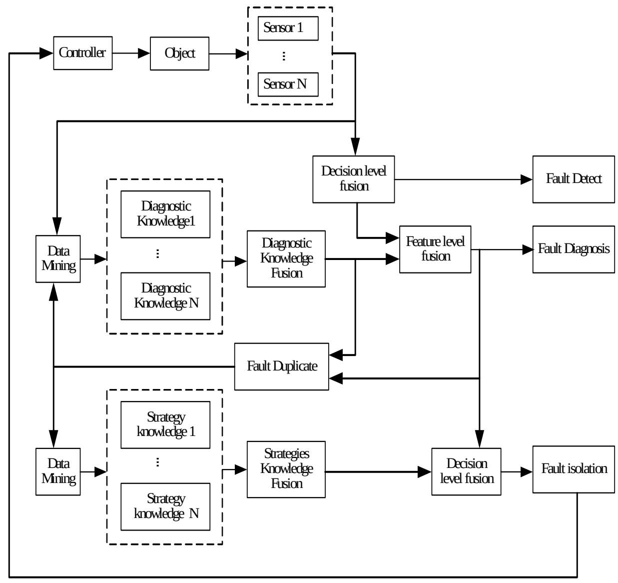

Fig. 5. Intelligent Fault Diagnosis Model on Multi-information Fusion

The observation space is divided into different characteristic field (each fault model corresponds to a region). And the characteristic region and the obtained information are changed and processed to get a judge rule. We can use two hypothesis and duality determine can be adopted for the simple detecting as to whether the faults will appear.

As far as certain fault model to be concerned, under the duality hypothesis condition, the observation space is divided into Z0 and Z1 regions. When the observation amount (or the transferred characteristic amount) is Z0, we can suppose no faults occur, otherwise faults occur. Getting proper determine region, we can make faults rate minimize when retrying.

The information obtained from sensor system (or distributed sensor system), on one hand, is stored into the database, and collect data; on the other hand, firstly carry on data fusion on detecting level to realize mentioned above fault monitoring, alarming and other primary diagnosis function.

C. Information Fusion and Fault Diagnosis on Characteristic Level

The characteristic fusion needs the fusion result on detecting level and at the same time needs the fusion result of diagnosis knowledge as to diagnosis object description. Diagnosis knowledge source not only includes priori various knowledge such as the knowledge based on rules, the knowledge based on dynamic state model, the knowledge based on fault tree model and the knowledge based on nerve web-net but also includes the new knowledge acquired by data collecting system regarding object operation, such as rules, classification, cluster and sequential matching etc. Comparing the established hypothesis (the known fault model), to test the observation amount, and to make sure which hypothesis can correspond to the observation amount.

For the case of multiple faults occur simultaneously, we often research to simply repeat or divide the method of single-fault diagnosis in previous time, while there are various shortcomings for the coupling faults and associated faults. If we can successfully apply the information fusion technology of multi-sensor, we will provide new ideas for establishment and development of fault diagnosis system. Multiple fault diagnosis problems caused not only from the actual occurrence of multiple faults, but also from observation process of sensor and uncertainty of diagnosis object. The actual sensor system always exist inevitable measurement errors, diagnostic systems are also lack of prior knowledge of the diagnosis object in different degrees. When faults occur, we often can not determine the number of faults or determine which generated the observation data by the actual fault or the noise or interference.

These uncertainty factors damage the relationship between observational data and fault sources, it needs information fusion in feature level, that is fault diagnosis. To ensure the correctness of the fusion results of diagnostic knowledge, we make the fault re-appear under artificial or real conditions for certain fault situation (the data can be equally data mining), in order to verify the fusion results of diagnostic knowledge. Combining the fusion results of diagnostic knowledge and the data in detecting level, we can fuse the data of feature layer; correspond to realize the diagnosis function of fault diagnostic system.

D. Information Fusion and Fault Isolation on Decision Level

Information source of decision-making level comes from the results of data fusion and knowledge fusion on the feature level. According to the results of data fusion on the decision-making level, we can take corresponding fault isolation policy to realize fault detection, fault diagnosis, etc. The ultimate purpose of fault diagnosis system is to use of the countermeasure under fault state, including fault isolation, reducing the amount of use and other measures, etc. At the same time, after using the countermeasure, the typical case is valuable experience, It will be stored into the database and prepare for decisions fusion in future through necessary data mining.

VII. Fault Diagnosis Development Trend Based on Multiple Information Fusion Technology

Information fusion technology makes full use of various multiple sensor information processing capability, and realized the equipment of real-time monitoring, mutation process signal forecast and warning. Therefore, it has higher precision and reliability than the previous fault diagnosis method. Information fusion is not a single technology. It is a comprehensive theory and method that it includes mathematics, pattern recognition, uncertainty theories, signal processing, computer science, automatic control theory, artificial intelligence, neural network etc. It is also a new research direction, and is constantly changing and developing. At present, the key problem based on information fusion fault diagnosis basically has the following several aspects:

a) In many cases, information is hided in the state measurement. However, the measurement is the uncertainties. In other words, the information is not sufficient, which will limit the quickness and accuracy of the fault recognition. Therefore, estimating state or parameter can obtain the data information that it is required but can not be measured. The analytical model, the signal processing and knowledge three kinds of methods exactly corresponds to the information fusion processing data grade, characteristic class and decision level three function levels. Therefore, the fusion results of the different levels are respectively made as the diagnostic system of relevant information, and are synthetically disposed, so as to achieve the purpose of various methods integrated.

b) The synchronous fusion problem research is the most in the multiple sensor data fusion estimation theory. However, the asynchronous problem is frequently encountered. Due to the different sensor has different sampling rate, and different sensor has inherent delays and transmission delay. Therefore, the fusion estimation of asynchronous multiple sensor state or parameters is a difficult problem.

c) In order to improve equipment fault diagnosis accuracy, the genetic algorithm, gray theory and the neural network are combined, so as to the equipment fault diagnosis. The intelligent information processing methods are used to perfect fault samples, and further developed and perfected intelligent fault diagnosis system.

d) The fault tolerance or robustness of fusion system is improved, so as to make handled properly the fusion system conflicting information or the error message that the sensor fault has caused, and make a reasonable response.

e) The real-time of fusion system is improved. With the complexity of the monitoring system, the information to be processed by the information fusion fault diagnosis system increases and the information processing cycle increases, leading that the real-time of the fusion system can not be guaranteed.

f) The performance of the information fusion fault diagnosis system is evaluated. For different design options of the same system or multiple design options of different systems, how to establish a reasonable mathematical model to evaluate the performance of the system and further select the best design option, which is also the subject of further study.

VIII. Conclusion

This paper bases on the characteristics of modern fault diagnosis system and the information fusion of multi-sensor, analyzes the relationship between fault diagnosis and information fusion, study the three layers structure of multi-sensor information fusion and the division for fusion content, also establishes intelligent fault diagnosis model for multi-information fusion. This model has common meaning, it can be extended to the system monitoring and diagnosis system for the large type equipments as well as production process.

At the same time, the development trend of fault diagnosis based on multi-information fusion is analyzed and key problems in fault diagnosis are pointed. As multi-sensor information fusion technology involves multi-disciplinary, multi-field Meanwhile, multi-sensor data fusion technology based on the fault diagnosis will continue to improve so as to obtain a wider range of applications remote processing and fusion integrated), Therefore, more accurate and more complete judgments can be obtained using information fusion than a single information source.

With the development of science and technology, the new, more efficient method of information fusion theory and technology will continue to appear. At the same time, the fault diagnosis methods based on multi-sensor data fusion technology will continue to improve so as to obtain a wider range of applications.

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