Analysis of Multi-sensor Data Fusion Architecture and Method

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Abstract: With the rapid development of new technologies such as electronic information technology, Internet of Things, artificial intelligence, robotics, industrial Internet of Things, intelligent manufacturing, intelligent monitoring and driverless driving, higher requirements for multi-sensor technology and its data fusion have been Become a strong support for the development of these new technologies. This paper introduces the process and main features of multi-sensor data fusion, and conducts in-depth analysis from multi-sensor data level fusion, feature level fusion and decision level fusion. It summarizes the current application of multi-sensor data fusion technology and puts forward the idea that it should be further studied in the future.

1. Introduction

As a device with information detection and object sensing capabilities, the sensor is the basis for automatic detection and control. In addition to being widely used in the field of general equipment, today's sensors are more used in Internet of Things, environmental monitoring, bioinformatics, medical image diagnosis and processing, fault diagnosis systems, artificial intelligence, intelligent manufacturing, intelligent robots, driverless, Meteorological forecasting and military security have brought new ideas and breakthroughs for the development of new technologies.

Since a single sensor provides less information and a single data type, and a single sensor is easily interfered and affected by various factors in a complex environment, it is difficult to meet the requirements of today's complex intelligent systems for multi-target sensing detection, which seriously affects data. The accuracy, and even the resulting system control flaws. Many modern advanced and complex systems require the use of multiple sensors to compensate for the deficiencies of a single sensor system. Multi-sensor data fusion can improve the performance of intelligent monitoring systems.

Multi-sensor data fusion processing technology has gradually become a new application form in the field of sensor data processing. Multi-sensor data fusion is based on modern computer technology. By synthesizing the source data perceived by sensors at different locations, the multi-sensor joint advantage is utilized to make accurate estimation and complex processing of the observed objects.

It can be said that the construction and development of multi-sensor information fusion system is an important support for the development of new technologies today. Research on multi-sensor data fusion processing is also a hot research topic. How to further improve the reliability, security and effectiveness of multi-sensor data fusion still needs in-depth research. This paper discusses and analyzes the multi-sensor data fusion model system and method.

2. Main features of multi-sensor system

2.1 Advantage performance.

Compared with single sensor systems, multi-sensor data fusion systems have the following advantages [1].

(1) Have a strong ability to survive. When there are several sensors that are subject to interference, there is always a sensor that can provide the data.

(2) It is possible to expand the coverage of the space. The spatial coverage is extended by the connection of multiple sensor active areas.

(3) It has real-time performance. At the same time, more information can be obtained, which greatly improves the recognition efficiency of the system.

(4) Increased credibility: the same target and event are confirmed by one or more sensors;

(5) Reduce the uncertainty of information. The combined data sensing of multiple sensors reduces the uncertainty of target and event perception.

(6) Improved spatial resolution. Multiple sensors can achieve higher resolution than a single sensor.

(8) The spatial dimension of the measurement increases. The probability of being disturbed and destroyed is reduced.

2.2 Inadequacies.

Although multi-sensor systems can get more data about the system or target, the use of multiple sensors will bring the following shortcomings.

(1) Multi-sensors form signals of different channels during signal transmission.

(2) The same signal forms different characteristic information.

(3) In multi-sensors, different diagnostic approaches and methods may lead to biased diagnostic conclusions.

(4) Monitoring information and diagnostic decision information from multiple sensors have certain uncertainties.

3. Data fusion architecture

Due to the uncertainty of the multi-source data stored in the sensor, such as data redundancy, improving the accuracy of the data becomes an important issue that restricts the multi-sensor system exhibition. Nowadays, it is generally thought to solve this problem by means of data fusion. The main principle is to measure the same object with multiple sensors, so as to obtain the multi-information of the object, and integrate, analyze and extract the information to obtain the pair. Sensing the better expression of the object.

3.1 Multi-sensor data fusion structure analysis.

In the multi-sensor data fusion system, from the relationship between the sensor and the data fusion convergence center data stream, the structure of the data fusion has the following forms.

(1) Serial fusion

The data fusion process of the serial multi-sensor first fuses the information of the two sensors, and then fuses the results of the first two fusions with the data collected by the third sensor, and sequentially performs until all the sensors collect. The data is all merged and completed.

When multi-sensor data is serially fused, the current sensor first receives the result of the output of the previous level sensor. That is to say, each sensor in the system must have the function of receiving information, processing information, and also integrating data. . The last sensor combines the data from all pre-sensor outputs, and the output from the last sensor will be the result of the entire serial fusion system. It can be seen that in the serial data fusion, the output of the front-end sensor has a relatively large influence on the output of the rear-end sensor. The way is shown in Figure 1.

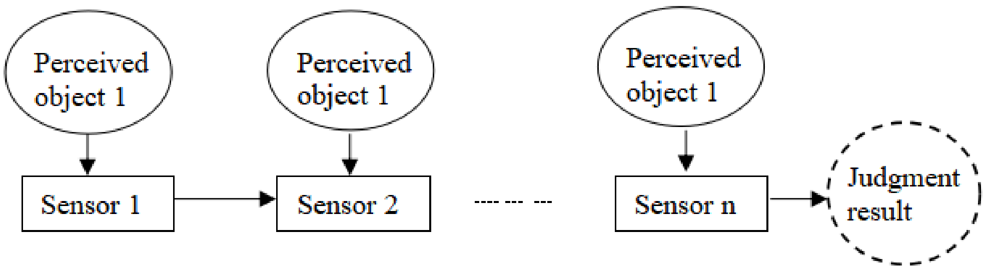

Fig. 1 Serial sensor data fusion structure

3.2 Parallel fusion.

In the case of multi-sensor parallel data fusion, each sensor directly transmits the respective perceived output data to the convergence fusion processing center, and the sensors are independent and parallel, with no influence on each other. The convergence data fusion center performs comprehensive processing on the data transmitted by each sensor according to an appropriate method, and then outputs the final result. As shown in Figure 2, the parallel fusion mode.

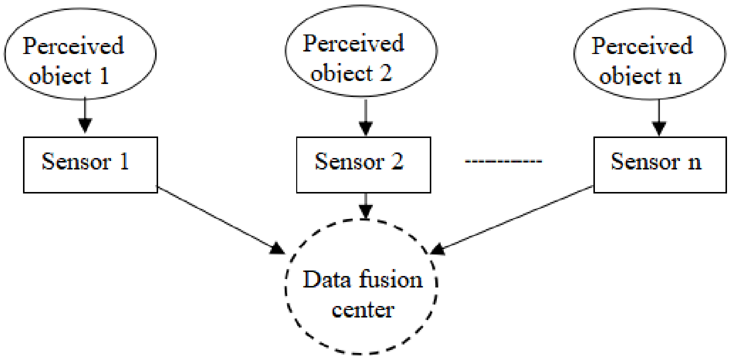

Fig. 2 Multi-sensor parallel data fusion structure

In multi-sensor parallel data fusion, since there is no mutual influence between the outputs of each sensor, the efficiency of sensor transmission is higher than that of serial mode, but the workload of convergence center will increase, so it is necessary to have high efficiency in convergence center. Processing algorithms and strong processing power.

If in a multi-sensor system, there is serial fusion and parallel fusion, that is, a combination of two fusion methods, it is called hybrid fusion. Such a structural system is more complicated in data fusion.

4. Level analysis of multi-sensor data fusion

If the analysis is performed from the level of multi-sensor data fusion, according to the data hierarchy, the data fusion is divided into three levels: pixel-level data fusion, feature-level data fusion, and decision-level data fusion [2].

4.1 Pixel level fusion.

The so-called pixel-level multi-sensor data fusion is the fusion of data directly on the original data layer collected by the sensor. That is, the raw data perceived by various sensors are comprehensively analyzed without being processed. Obviously this fusion method is a relatively low-level form of data fusion. In pixel-level data fusion, the matched sensor data is directly fused and then correlated based on the original data. At this time, it is necessary to ensure that the data of the same target or state is fused, that is, the consistency of the target and the data is ensured. After the original data of the sensor network is fused, the identified processing result is equivalent to the processing of the single sensor information, because after the redundant information is removed, the data is consistent, and the data seems to come from one sensor. Pixel-level data fusion is shown in Figure 3.

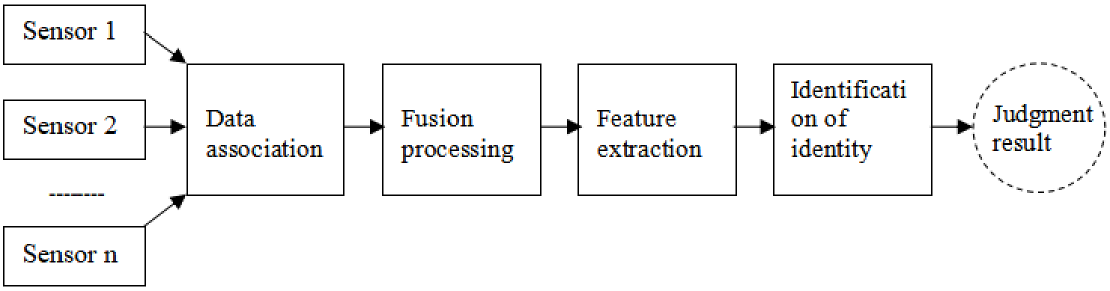

Fig. 3 pixel-level data fusion structure

(1) The role of pixel-level data fusion.

For the result of pixel-level fusion, on the one hand, it is used for monitoring and control of the diagnostic system; on the other hand, it provides data for feature layer fusion. The accuracy that can be achieved by pixel-level data fusion depends mainly on the accuracy of the physical model. The simplest and most intuitive pixel-level data fusion algorithm is the arithmetic average method and the weighted average method.

(2) Advantages and disadvantages of pixel-level data fusion.

Because pixel-level data fusion is a fusion of low-level data, it can protect field data as much as possible and provide data for higher-level data fusion. The disadvantage is that the amount of sensor data to be processed is relatively large, resulting in processing. Long time, affecting the real-time nature of the data. At the same time, due to the inaccuracy, incompleteness and instability of the original data itself, it requires strong error correction capability in data fusion, which also adds complexity to data fusion.

4.2 Feature level fusion.

Features are used to represent the behavior, performance, and function of the research object, while distinguishing between similar or dissimilar information. It can be seen that the feature level data fusion method first extracts a set of feature information from the raw data collected by each sensor, and then fuses each group of feature information.

Feature-level data fusion is essentially a pattern recognition problem. The multi-sensor system increases the spatial dimension of the feature information by identifying feature information that provides more targets. Before the feature level data fusion, the sensor data is preprocessed, and the feature and data matching criteria are extracted from it. This process is realized by the sensor information transformation method, that is, the data input by each sensor is transformed into a unified data Table. Achieve the same data structure form and then match the data. After the data is aligned, the features must be correlated and the target must be fused.

For feature-level data fusion, it is first necessary to make effective decisions on pixel-level fusion results, and then to identify faults, and finally provide information for decision-level fusion. Feature level data fusion, as shown in Figure 4.

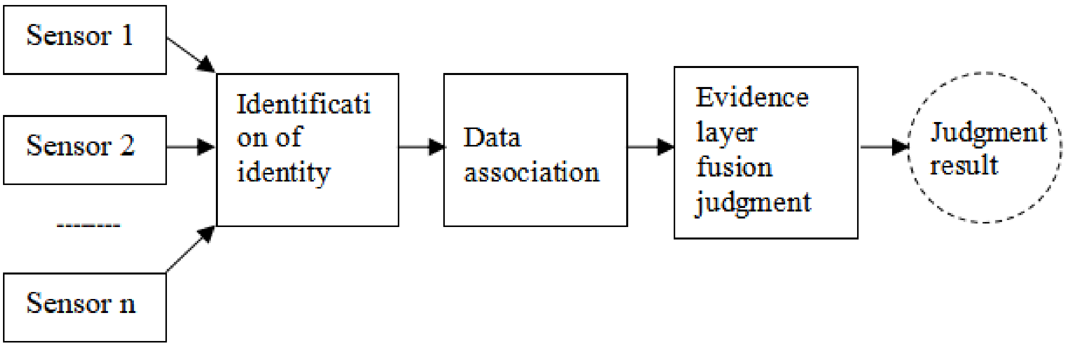

Fig. 4 Feature Level Data Fusion Structure

Feature-level data fusion facilitates real-time data processing, and feature information can be extracted. Feature information can be used for decision analysis.

4.3 Decision-level fusion.

Compared with decision-level fusion, it is a higher level of fusion, and its fusion object is the individual decision of each sensor. Each sensor performs transformations and processing, including pre-processing, feature extraction, recognition, or decision. The data passing through each sensor undergoes feature level fusion and feature information extraction. Complete their own decision-making or identification work before integration, and then merge these decisions to achieve a decision result with overall consistency. At the decision-making level, the amount of data transmission is small, the dependence on the sensor is small, and it has good fault tolerance, but the disadvantage is that the operation cost of the initial decision is high. The joint inference results are finally obtained through the association processing and the decision-level fusion judgment. The architecture is shown in Figure 5.

(1) The main advantages of decision-level integration. In the decision-level fusion, the amount of data is relatively small, the dependence on the sensor is small, and it is fault-tolerant.

(2) The shortcomings of decision-level integration. The original sensor data should be pre-processed to obtain the respective judgment results, but the pre-processing cost is relatively high.

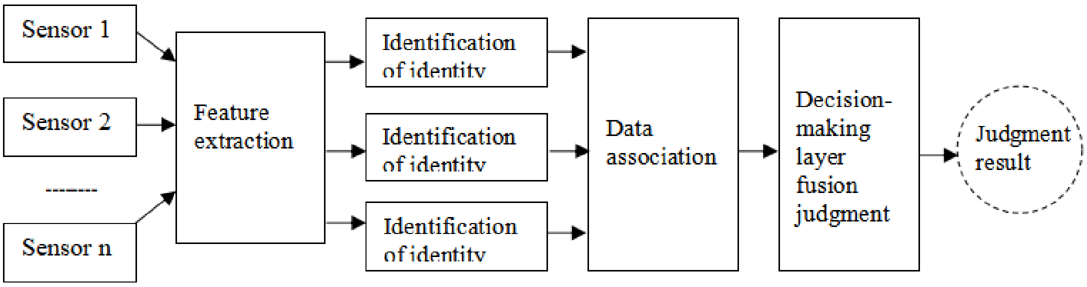

Fig. 5 Decision-level data fusion structure

5. Comparison of three data fusion levels

Through comparative analysis of sensor dependence, data volume, traffic, etc., it can be seen that since data-level fusion is the most basic level of convergence, data fusion can be performed while preserving as much information as possible, but for sensors and communications. The requirements of capability and processing cost are relatively high. Conversely, when the decision-making layer combines multi-source heterogeneous data, only small data line communication is required, and good communication volume is also provided, but the fusion precision is low. The performance of feature-level data fusion is centered, combining the advantages and disadvantages of the other two levels.

6. Multi-sensor data fusion target state estimation analysis

From the perspective of target state estimation, according to different data processing methods, multi-sensor data fusion systems can be divided into distributed, centralized and hybrid [3].

(1) Distributed. The distributed structure has corresponding processing units at each independent node, which is used to initially process the original information acquired by the sensor, and then sent to the unified information fusion center, and cooperate with the data fusion algorithm for multi-dimensional optimization, combination and reasoning to obtain the final result. .

(2) Centralized. In a centralized structure, the raw data acquired by multiple sensors is sent directly to the data fusion center without any processing. The advantage of this structure is that it has high fusion precision, various algorithms and good real-time performance. The disadvantage is that the data flow is single, the processing center has a large amount of computation, and the hardware cost is increased.

(3) Mixed type. Hybrid has both distributed and centralized structure, taking into account the advantages of both, and can complete the information processing work flexibly and reasonably according to different needs, but the structural design requirements are high, and the stability of the system is reduced.

7. Brief analysis of multi-sensor data fusion techniques and methods

In the multi-sensor data fusion system, various multi-sensor data fusion methods can be used to effectively fuse various types of sensor data according to actual needs. At present, there are some technical methods for multi-sensor data fusion as follows. [4].

(1) Weighted average method

The weighted averaging method is the simplest data fusion algorithm. The method performs weighted averaging on the sensor data to obtain the result of the fusion.

(2) Neural network method

The neural network-based multi-sensor data fusion algorithm converts data information into a knowledge base by using a large number of neurons with nonlinear mapping relationships. In this way, knowledge acquisition and associative reasoning can be automatically performed, thereby integrating uncertain and complex data through learning and reasoning into data that the system can process.

(3) Kalman filtering method

The Kalman filtering algorithm can obtain the statistically unique optimal estimate in the case of a linear system with an error of Gaussian white noise model. The extended Kalman filtering algorithm and the Kalman filtering based on strong tracking can be applied to nonlinear systems. Kalman filtering is a widely used data fusion method.

(4) Bayesian estimation method

The Bayesian estimation method uses the probability density function to represent the source information, optimizes the fusion data, combines the sensor information according to the probability relationship, and expresses the measurement uncertainty by the conditional probability. Bayesian estimation is also a common method in data fusion.

(5) D-S evidence theory

D-S evidence theory is an extended form of Bayesian estimation. Bayesian estimation method needs to give prior probability in advance, while D-S evidence theory can clarify information in the absence of a priori information. It is a theoretical method of imprecise reasoning.

8. Conclusion

Multi-sensor data fusion technology is an indispensable part of the development of new technologies. Multi-sensor data fusion technology can not only expand the coverage of observation data, but also improve the confidence and resolution of data, and enhance the fault tolerance of application systems. Ensure the effectiveness and reliability of the control process [5]. At the same time, it also puts forward higher requirements for the fusion technology of the application system, and still needs to conduct more in-depth research on the existing fusion mode and technology. Continuously innovate, optimize and improve multi-sensor data fusion algorithms. To have a sufficiently optimized fusion algorithm and a large number of prior models, the speed and correctness of the final decision can be achieved. At the same time, attention should be paid to the security of data in the process of multi-sensor data fusion, such as the protection of data privacy during data fusion. Also consider the software and hardware issues in the system to achieve a reliable, secure, efficient and practical data fusion system to promote the continuous advancement and development of other new technologies.

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