# A survey of Information Fusion Technology Based on Multi-sensor

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## Abstract

**With the need of military and civil, the requirement of information intelligent processing of multi-sensor system is increasing. In this paper, the development process, basic concepts, principles, architecture, hierarchy and common algorithms of multisensor information fusion technology are introduced in detail. Finally, the application and existing problems of multisensor information fusion technology at present are analyzed, and its development direction is prospected.**

## Keywords

**Multi-sensor, Information fusion, Algorithm problems, Direction outlook.**

## 1. Introduction

In the future war, changes are unpredictable and fast. The traditional war mode has developed into a modern war mode integrating land, sea, air, space and information. The whole space is full of all kinds of enemy and US signal sources, multi-source information, diversification of channels, high-intensity electronic countermeasures and the existence of a large number of stealth targets, which make a single sensor unable to grasp the situation completely to meet the needs of the war, so it must be operated The observation information is provided by multi-sensor cooperative work, including radar, infrared, laser, electronic support measures, etc., and all information is integrated, analyzed and processed together to get relatively real and complete information, which requires multi-sensor information fusion system. Therefore, multi-sensor information fusion, a new subject, has developed rapidly, and has been widely used in modern C3I (command, control, communication and intelligence) systems, various weapon platforms and many civil fields.

## 2. Review of Research Development

### 2.1 Research and Development in Foreign Countries

The prototype of multi-sensor information fusion technology first appeared at the end of the Second World War. At that time, radar and optical sensors were used simultaneously in the fire control system of anti-aircraft gun. Through the combination of two kinds of sensor information, not only the aiming accuracy is effectively improved, but also the ability of anti bad weather and anti-interference is greatly improved. However, at that time, the comprehensive evaluation of the two sources of information can only be done manually, the low quality and slow speed did not have a significant impact on the war situation at that time, so people did not pay enough attention to it. In the 1970s, American research institutions began to study the automatic integrated processing of information. In 1973, information fusion was officially proposed in the sonar signal processing system funded by the US Department of defense, and it was the earliest embodiment in the system. The U.S. military has gradually launched the research of C3I system, and plans to use multi-sensor to collect battlefield information [1]. The U.S. has developed enemy situation analysis system and full source information analysis system by the 1990s. In 1996, computer elements were added to C3I, and C4I (command, control, communication, computer and intelligence) system with information fusion as the core was established. Isif (International Society of information fusion) was founded in 1998 in the United States, and an international academic conference on information fusion was held every year. The research results and progress in this field were introduced systematically and periodically, marking

that multi-sensor information fusion as a new discipline has been recognized by the international academic community.

### 2.2 Domestic Research and Development

The research of information fusion technology in China started relatively late, and the speed is relatively slow. In the domestic literature, information fusion technology and its related research began to appear in the late 1980s. At the beginning of 1990s, with the successful development of various kinds of sensors, with the support of the military and various fund departments, domestic research on information fusion has made some achievements. At the same time, a large number of monographs and translations on information fusion technology have been published, among which the most representative ones are: the translation of multi-sensor data fusion theory by Dai Yaping, Yu Guanghui and Liu Zheng And application [2], information fusion technology by Li Hongzhi [3].

## 3. Basic Concepts, Principles and Architecture

### 3.1 Basic Concepts

Information fusion (also known as data fusion) is a kind of processing process of multi-level and multi-faceted synthesis of multi-source data information such as detection, combination, correlation and estimation to obtain timely, complete and accurate target attributes and states.

Multisensor information fusion is a process of information processing that uses computer technology to automatically analyze and synthesize the information and data from multisensor or multi-source under certain criteria to complete the required decision-making and estimation. [4]

It can be seen from the definition that the basis of multi-sensor information fusion is multi-sensor system, the processing object is multi-source information collected by multi-sensor, and the core is coordinated optimization and comprehensive processing of the collected information.

### 3.2 Basic Principles

The human brain has the ability to comprehensively process the information (scene, sound, smell, etc.) detected by various functional organs of the human body (ears, eyes, mouth, nose, etc.) and prior knowledge, so as to make judgments on the events and environment around and control the human body in the next step. This process is the only judgment to transform all kinds of information (image, sound, smell, etc.) into the surrounding environment, which requires a lot of analysis and comprehensive intelligent processing, as well as a knowledge base suitable for interpreting the meaning of combined information.

In fact, multi-sensor information fusion is a kind of functional simulation for human brain to deal with complex problems synthetically. Different characteristic information provided by various sensors is processed by multi-level and multi-dimensional information complementation and optimization combination, and finally the consistent interpretation of observation environment is produced. By using the advantage of multiple sensors cooperating with each other, the system can obtain better performance than the system composed of its components, thus improving the intelligence and effectiveness of the whole system.

### 3.3 System Architecture

According to different data processing methods, there are three kinds of architecture of information fusion system: distributed, centralized and hybrid.

Distributed fusion. Firstly, the original data obtained by each independent sensor is processed locally, and then the results are sent to the information fusion center for intelligent optimization and combination to obtain the final results. Distributed fusion has low demand for communication bandwidth, fast computing speed, good reliability and continuity, but the tracking accuracy is far from centralized high; distributed fusion structure can be divided into distributed fusion structure with feedback and distributed fusion structure without feedback.

Centralized fusion: it is to send the original data obtained by each sensor directly to the central processor for fusion processing, which can realize real-time fusion. Its data processing accuracy is

high, the algorithm is flexible, and its disadvantages are high requirements for the processor, low reliability, large amount of data, so it is difficult to achieve.

Hybrid fusion: that is to say, some sensors adopt centralized fusion and others adopt distributed fusion. The framework has strong adaptability, takes into account the advantages of centralized fusion and distributed, and has strong stability. But the structure of hybrid fusion is complex, which greatly increases the cost.

## 4. Hierarchical Structure and Theoretical Algorithm of Multisensor Information Fusion

### 4.1 Hierarchy

There are essential differences between multi-sensor information fusion and traditional signal processing methods. The multi-sensor signal processed by information fusion has a more complex form and level. The representation level of these information includes data level, feature level and decision level. According to the information level of the fusion system, information fusion methods are generally divided into data level fusion, feature level fusion and decision level fusion. Data layer fusion, that is, low-level fusion or pixel level fusion, is to fuse directly on the original observation information layer collected by the sensor, that is, to synthesize, analyze and process the original information before preprocessing. Its advantage lies in the ability to maintain as much field data as possible, which cannot be provided by other fusion levels, but there are limitations in the following aspects: the number of required sensors is too large, so the replacement price is high, the time is long, and the real-time performance is poor; the instability, incompleteness and uncertainty of the original information require a high error correction ability in fusion; the information of each sensor is required to have The accuracy of the same pixel calibration, so the information of each sensor must come from the same sensor; the data communication is large, and the anti-interference ability is poor.

Feature level fusion is intermediate fusion or feature level fusion. Firstly, the original information from sensors is extracted, and then the feature information is synthesized, analyzed and processed. The advantage of feature layer fusion is that it can compress some information, and it is good for real-time processing. Because the extracted information is directly related to decision analysis, the fusion result can give the feature information needed by advanced analysis to the maximum extent. Feature layer fusion is becoming more and more mature in theory and application, and has initially formed specific solutions to the problems. In the three levels of fusion, the feature layer has established a set of effective feature association technology, which can be said to be the most perfect to some extent, with good application and development prospects.

Decision level fusion refers to advanced fusion or decision level fusion. After each sensor completes the original information processing (preprocessing, feature extraction, recognition or judgment), it establishes the preliminary conclusion of the observed object, and carries out the fusion processing of local decision level through each sensor association to obtain the final fusion result. It has the advantages of small amount of information transmission, high flexibility, but high cost of preprocessing. Decision level fusion has fault tolerance, and the output is a joint decision result. In theory, it should be more accurate or more clear than any single sensor decision. Decision level fusion has low requirements for information transmission bandwidth, which can effectively fuse different types of information reflecting various aspects of the environment or target, and can process non synchronous information. Therefore, the current information fusion in the decision level is introduced It has been studied by many scholars. However, due to the time-varying dynamic characteristics of environment and target, the acquisition of prior knowledge, and the huge quantity characteristics of knowledge base, the development of decision-making level fusion theory and technology is still hindered.

### 4.2 Theoretical Algorithm

Theoretical algorithm is the core of information fusion and the realization method of information fusion. The basic requirements of information fusion method are parallel processing ability and robustness, and the operation speed and accuracy as well as the coordination ability with different technologies and methods are also important factors. At present, there are many information fusion methods, but there is no one algorithm that can process all kinds of sensor information fusion, which is generally based on specific application occasions. Here are several mainstream algorithms:

Weighted average method：Weighted average method is the basic method of index synthesis. Its essence is to process the data information from each sensor and then carry out weighted average according to the weight of each sensor. The weighted average value is the fusion result. This method is simple and practical, but it requires a detailed analysis of the system and sensors to obtain accurate weights.

Kalman filter：Kalman filter processing is divided into two types: decentralized Kalman filter and extended Kalman filter. The former can make the data fusion completely decentralized, while the latter can effectively overcome the impact of data processing errors and instability on the information fusion process. The process of Kalman filter processing information is generally prediction and correction. Its function is not only algorithm, but also a set of very useful system processing scheme. It uses the method of iterative and recursive calculation in mathematics to provide an effective statistical optimal estimation for the fusion data, and has little storage space and calculation requirements, which is suitable for the environment with limited data processing space and speed. Its limitation lies in the poor real-time and reliability under the condition of a large amount of redundant combined information and a large number of subsystems.

Artificial neural network method：By imitating the structure and working principle of human brain, this method takes the data obtained by sensors as the input of network, and completes certain intelligent tasks on the corresponding machine or model through network training to eliminate the interference of non-target parameters. Neural network has strong fault tolerance, self-adaptive ability, self-learning ability and self-organization ability. Using the signal processing ability and automatic reasoning ability of neural network, it has obvious effect on eliminating the cross influence of various factors in multi-sensor cooperative work, and it is easy to program and stable in output [5].

Bayesian inference：Bayes reasoning is a method to fuse low-level data in static environment, but it must be consistent, and its information is described as probability distribution. This method is suitable for the processing of uncertain information with additive Gaussian noise, but it is difficult to calculate the prior probability of each sensor to the target category, and its generality is poor.

## 5. Application Status

Multisensor information fusion technology originated and applied in the military field, then with the promotion of the theory and technology, the technology has been widely used in civil and military fields.

Military applications include a wide range of fields, from individual combat system to tactical and strategic command system, and the specific application scope includes: Marine Surveillance System for detection, tracking and identification of underwater targets such as submarines and torpedoes; air-to-air and ground-to-air defense system for detection, tracking and identification of enemy aircraft, missiles and anti aircraft weapons; and air-to-air defense system for intelligence, target acquisition, detection and identification An information collection system for covert targets on land; an air control system that uses radio and radar to provide aerial images.

Civil applications mainly include: criminal investigation, such as using infrared, microwave and other sensor equipment to detect the concealed contraband; medical and health care, which can make a reasonable treatment plan for patients through information fusion of medical records, family history, personal history, climate and other information; industrial robots, typical examples such as using

stereo vision, ultrasonic and tactile sensors Stanford robot, which navigates in unstructured human environment, combines hearing, vision, touch, laser ranging and other sensors to make it work in unknown environment; it can also be used in intelligent manufacturing, intelligent transportation, non-destructive testing, environmental monitoring, network monitoring system, remote sensing, security, finance and other fields. In reference [6], the typical examples of information fusion technology in remote sensing applications are introduced.

## 6. Prospect of Research Direction

Because multi-sensor system is the basis of multi-sensor information fusion, and sensor information is the object of multi-sensor information fusion, coordination and optimization processing are the core of multi-sensor information fusion. In my opinion, the research direction of multi-sensor information fusion technology in the future can be summarized as follows

(1) System theory research. Research and establish a unified information fusion theory, mainly including multi platform signal feature extraction and establishment, general model of data fusion and signal fusion, functional structure, optimization design and evaluation criteria. In reference [7], the sub network is used to replace the middle hidden layer of the traditional neural network structure, and the structure model of the array neural network is proposed. The sub network is used to realize information differentiation and fusion.

(2) Information fusion technology in complex environment. In reference [8], Cheng Hongxia and others fused the environmental information provided by a variety of sensors through the independent control of the platform decision-making layer, forming a comprehensive result of external complex environmental characteristics, realizing the unmanned platform to avoid obstacles accurately and quickly.

(3) Further improve the fusion algorithm. In reference [9], Li Guang and others used BP neural network for simulation and further used D-S evidence theory fusion algorithm, which not only improved the accuracy of data, but also increased the stability of the system, thus greatly improving the automation level of the system.

(4) Further deepen the application research. Multi-sensor information fusion technology has been widely used in military and civil fields, but the fusion is relatively single and independent. The development of information, sensor management and automatic control system should be further deepened. For example, the structure of fuzzy neural system proposed in [10] can dominate the behavior based mobile robot in unknown environment.

## 7. Conclusion

At present, multisensor information fusion technology in China has been applied in military, industrial and other fields, but it is still in its infancy. With the in-depth study of scholars, large-scale, distributed, intelligent, multi-sensor fusion system combined with different fusion methods has become an inevitable trend of development, and multi-sensor information fusion technology has become an inevitable trend in the wider field of promotion and application.

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