

Research on Multi-Source Information Fusion Technology

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Abstract. Multi-source information fusion technology has developed rapidly since it was publicly proposed in the 20th century. The article first reviewed the development history of information fusion. Combining domestic and foreign research results and current situation, this paper introduced several classical functional models of information fusion and the mathematical theoretical support of information fusion. Finally, the application status of multi-source information fusion technology was summarized systematically.

1. Introduction

In nature, humans and other animals have the ability to fuse multiple sources. When people and other animals are in a certain natural environment or observing interested objects, they can transmit the target features perceived by visual, olfactory, taste, auditory and other senses to the brain by using human neural network, and then the brain synthesizes these features according to some unknown rules, thereby obtaining a unified comprehending and understanding of environmental objects, and make corresponding actions and decisions. This process of perception-to-cognition is the multi-source information fusion process of organisms. People have studied the biological information processing process and tried to simulate the process of perception and cognition of organisms through machines, which led to the multi-source information fusion.

Multi-source information fusion is an interdisciplinary subject, which integrates control, electronic information, computer and mathematics [1]. With the development of technology, especially the rapid development of sensor technology, computer technology and information processing technology, higher requirements are put forward for the development of information fusion. In recent years, with the sharp increase in the demand for various multi-sensor platforms and systems, information fusion has entered a peak period of development, and various new theories, new methods and new technologies for information fusion are emerging one after another. In the field of information fusion, a number of high-level academic monographs have been published. At the same time, many countries in the world have adopted information fusion technology as a high-tech development in the 21st century. Therefore, the theory and technology research of information fusion has far-reaching significance.

2. Development Status of Information Fusion Technology

Information fusion technology first appeared in the field of military science. The US military first proposed the concept of data fusion when using multiple independent sonars to automatically detected the position of enemy ships in a certain sea area. Subsequently, the battlefield management and target detection system were developed, which promoted the formation and development of the subject of multi-source information fusion [2]. After the climax of continuous research from the early 1980s to the present, information fusion theory and technology have further developed rapidly.

2.1 Foreign research status

For the methods of information fusion, foreign research is more in-depth. Y.Bar-Shalom, R.Singer,

W.D.Blair, D.B.Reid, S.S.Blackman, A.Poore, X.R.Li, T.Kirubarajan, K.C.Chang and other scientists have made outstanding contributions to the tracking of moving targets and data association. They have proposed a series of classical algorithms, including joint probability data association, multi-hypothesis tracking, multi-dimensional assignment algorithm, interactive multi-model filtering, fusion algorithm based on random set theory, D-S evidence theory, etc [3].

The application scope of foreign information fusion technology is also expanding.As an independent discipline, information fusion has been successfully applied in military fields such as military command automation, strategic early warning and defense, multi-target tracking and precision guided weapons[4-5],and gradually radiate to many civil fields such as intelligent transportation, remote sensing monitoring, medical diagnosis, electronic commerce, artificial intelligence, wireless communication and industrial process monitoring and fault diagnosis [6-8].

2.2 Domestic research status

China's research on information fusion technology is relatively late, and some articles have been published since the 1980s.In recent years, with the technical investment of some universities and research institutes, information fusion technology has made great achievements in China, and its application field has been expanding. In the power industry, scholars mostly used D-S evidence theory to establish safety state assessment model [9-10]. In the mining industry, many scholars have tried to combine neural network with other methods to evaluate the working environment of mines and miners [11-12]. In the transportation industry, information fusion is mainly used in road safety assessment and rail transit safety status [13]. In the construction industry, information fusion is mainly used in building construction safety warning and building energy consumption control, Fire detection and other aspects [14].

3. Models and Methods of Information Fusion Technology

3.1 Functional model of multi-source information fusion

The first institute to study multi-source information fusion is the Joint Directors of Laboratories (JDL) of the United States Department of Defense, which proposed the famous JDL model. After continuous revision and practice development, this model has been identified as the actual standard of the US defense information fusion system. The original JDL model considers the fusion process in four increasing levels of abstraction, namely, object, situation, impact, and process refinement. In 1999, Steinberg proposed a modified model based on the original JDL model. As shown in Figure 1,the model changed the three-level processing of the original model from "threat estimation" to "impact estimation", and successfully extended the application of functional models from the military field to the civilian field. In 2002, Erik. P. Blasch proposed a JDL-User model based on the basic JDL model, which was more practical and operable.

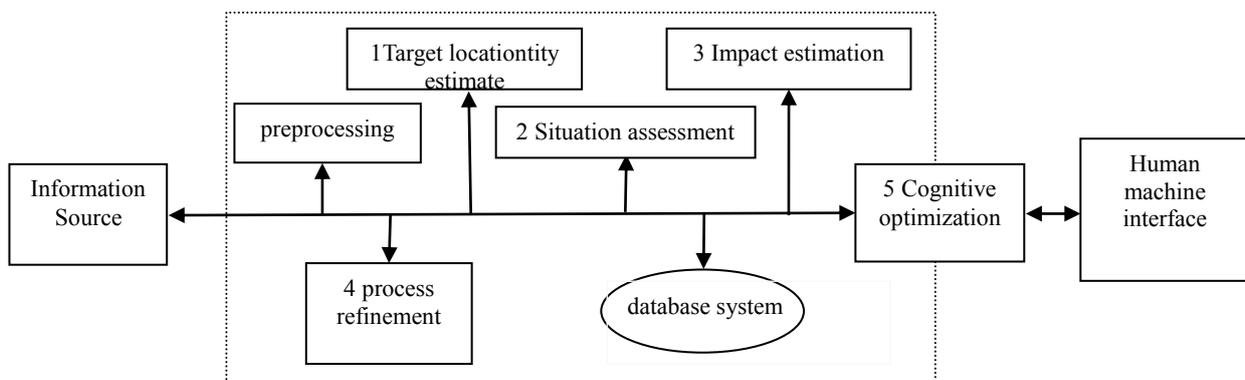


Fig. 1 JDL correction model.

M. Bedworth launched the waterfall model in 1994, which was commonly used in the UK's defense information fusion system. However, after long-term practical application, some scholars found that the model had some defects, and proposed a modified waterfall model. In addition to the classical models mentioned above, scholars also proposed the information loop model, Boyd model, and hybrid model. The intelligence loop model is a data fusion model for macro data processing. The Boyd loop model is used for military command processing and has been widely used for information fusion. The hybrid model synthesizes the advantages of other models, which can be widely used in many non-military fields.

3.2 The main method of multi-source information fusion

3.2.1 Estimation theory

Estimation theoretical methods include Kalman filtering for linear stochastic systems, extended Kalman (EKF) for nonlinear stochastic systems, strong tracking filters (STF), etc. With the increasing awareness of information fusion, more and more scholars have devoted themselves to the unscented Kalman filter (UKF) and discrete differential filter (DDF) with approximation accuracy up to the second order etc., and obtained a lot of valuable research.

3.2.2 Uncertainty reasoning method

In multi-source information fusion system, the information provided by various measurement sources has incompleteness, inaccuracy and ambiguity. In other words, the detection information contains a large amount of uncertainty, so the fusion center can only rely on determining information for processing and reasoning, achieving the purpose of target identification and attribute judgment. This method is the basis of target identification and attribute information fusion, including subjective Bayesian method, DS evidence reasoning method, DS_m T method, fuzzy mathematics theory method and possibility reasoning method, etc.

3.2.3 Intelligent computing and pattern recognition theory

Pattern recognition is a basic form of human natural intelligence. It is a process of distinguishing one kind of thing from another according to certain observations. At present, the theory of Intelligent Computing and pattern recognition applied in information fusion includes rough sets theory, random sets theory, grey system theory, information entropy theory, neural network, genetic algorithm, Bayesian network and so on.

There are many kinds of multi-source information fusion methods, so people can't easily determine which method is good or bad. Because each method has its advantages or disadvantages, and each method has a certain complementarity with each other. Therefore, the establishment of information fusion methods must be combined with the specific application background of multi-sensor information fusion. People can combine the advantages of two or more methods in the same information fusion system to ensure optimal information fusion results or decision-making.

4. Application of Multi-Source Information Fusion Technology

Multi-source information fusion technology was used as a secret application in the military field in the early days, aiming at the detection and early warning, location, tracking and identification of various military equipment or weapons (ships, aircraft, missiles) [15]. In recent years, multi-source information fusion system has also made considerable progress in civil applications, mainly in the areas of image fusion, industrial intelligent robots and intelligent transportation systems [15].

4.1 Strategic early warning system

Strategic early warning system is a classical application of multi-source information fusion technology in military field. The system is a perception system based on information fusion technology. Its main purpose is to observe and monitor dynamically the threatened flying objects

such as ballistic missiles and strategic bombers at long and ultra-long distances, so as to facilitate early detection and effective interception of threatening targets. Its sensing platforms, such as long-range early warning radars, early warning satellites, and early warning aircraft, detect and collaborate on a large span of time, space, and spectrum. Strategic early warning system needs to estimate the motion state of the target in real time, and identify the target's identity, category, situation, threat and environmental parameters.

4.2 Autonomous positioning and navigation system of multi-robot

Multi-robot autonomous positioning and navigation systems have typical characteristics in terms of information dimension and time scale ^[16]. In the environment of uncertain and completely unknown position, many robots in the system firstly extract and identify the features of environmental landmarks through their own sensors to obtain relative observation information. At the same time, their positions and landmarks are estimated. Under the cooperative work of multi-robots, with the movement of robots, the feature sub-maps of robots are fused to form a single and complete public environment map. At the same time, the motion trajectory of each robot is obtained. Perceptual means include sensors such as ultrasound, laser, infrared, and CCD cameras.

4.3 Intelligent transportation system

Through the research of key basic theoretical models, intelligent transportation system effectively uses the technologies of information, communication, automatic control and system integration to realize real-time, accurate and efficient transportation management in a wide range. The system uses sensors such as CCD, RFID and electromagnetic induction to realize vehicle identification and motion state estimation, and provides traffic flow, road condition, violation, unexpected accidents and scheduling of road vehicles.

5. Conclusion

This paper reviewed the research status of multi-source information fusion technology from the perspective of technology development, and pointed out its current development status and main application fields. Multi-source information fusion technology has received extensive attention in the past decade. Its theory and method have been applied to many research fields, and various new devices relying on multi-source information fusion technology are emerging. The research of multi-source information fusion technology not only has great theoretical significance, but also has far-reaching economic value. We should attach importance to this new information processing technology and actively carry out the basic theory and application research in this field.

References

- [1] Zhao Zonggui. Current Status, Concept and Structure Model of Information Fusion Technology[J]. Journal of China Academy of Electronics and Information Technology, 2006(04):305-312.
- [2] Pan Quan, Hu Yumei, Lan Hua, et al. Information Fusion Progress: Joint Optimization Based on Variational Bayesian Theory[J/OL]. Acta Automatica Sinica: 1-17[2019-05-29].
- [3] Li Ming. Research on Multi-source Information Fusion Problem[J]. Ship Electronic Engineering, 2017, 37(06):5-9.
- [4] Schade U, Biermann J, Miłosław Frey, et al. From battle management language (BML) to automatic information fusion[J]. 2007, 11(2): 84-95.
- [5] Chen P Y, Chen K C. Intentional attack and fusion-based defense strategy in complex networks[C]. Global Telecommunications Conference. IEEE, 2011:1-5.

- [6] Guo J, Du J, Xu D. Navigation and positioning system applied in underground driverless vehicle based on IMU[C]. 2018 International Conference on Robots & Intelligent System (ICRIS). IEEE Computer Society, 2018:13-16.
- [7] Neha J, Matthias B, Andrea E, et al. A review of the application of optical and radar Remote sensing data fusion to land use mapping and monitoring[J]. Remote Sensing, 2016, 8(1):70.
- [8] Wu D, Liu X, Xue F, et al. A new medical diagnosis method based on Z-Numbers[J]. Applied Intelligence, 2017, 48(4):854-867.
- [9] Zeng Kai, Yuan Dan, Liu Jianqin, et al. Fault Diagnosis for Transformer Based on Adaptive PNN Optimized by SA-PSO Algorithm[J]. Computer Measurement & Control, 2014, 22(04):1015-1017.
- [10] Miao Hongxia, Xiao Xuanxuan, Jiang Bing, et al. State evaluation of prefabricated substation based on information fusion[J]. Power System Protection and Control, 2017, 45(14):85-91.
- [11] He Jincan, Wang Huibin, Xu Lizhong. Monitoring and Analysis of Danger Resources Based on Multi-Sensor Management Technology[J]. Techniques of Automation and Applications, 2010, 29(09):50-52+56.
- [12] Jing Guoxun, Fan Ziqi. Method for Comprehensive Evaluation of Mine Environment Based on Information Fusion Technology[J]. Safety and Environmental Engineering, 2016, 23(06):90-94.
- [13] Li Xianyu, Guo Zhongyin, Wang Lu, et al. Multi-information Fusion Technology of Highway Traffic Lifeline Based on D-S Evidence Theory[J]. Journal of East China Jiaotong University, 2017, 34(03):88-94.
- [14] Zhang Liusheng. Research on Intelligent Building Fire Detection Based on Multi-sensor Information Fusion[D]. Jiangxi university of science and technology, 2013.
- [15] Zhang Yi, Luo Yan, Zheng Taixiong, et al. Mobile Robot Technology and Its Application [M]. Beijing: Electronic Industry Press. 2007:226-228.
- [16] He You, Wang Guohong, Peng Yingning, et al. Multisensor Information Fusion and Application [M]. Beijing: Electronic Industry Publishing House. 2006, 49 (3) :549—558.