THE IMPLEMENTATION OF DATA FUSION SYSTEMS

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1. Introduction

Data fusion systems seek to combine information from multiple sensors and sources to achieve improved inferences than those achieved from a single sensor or source. Applications of data fusion related to the Department of Defense (DoD) span a number of areas including automatic target recognition (ATR), identification-friend-foe-neutral (IFFN), smart weapons, battlefield surveillance systems, threat warning systems (TWS), and systems to support precision guided weapons. Waltz and Llinas [1], Hall [2], and Hall and Llinas [3] provide a general introduction to multisensor data fusion. Additional information can be obtained from the texts by Blackman [4], Antony [5], and Hall [6]. Data fusion systems typically use a variety of algorithms and techniques to transform the sensor data (e.g., radar returns, and infrared spectra) to detect, locate, characterize, and identify entities such as aircraft and ground-based vehicles. These techniques include signal and image processing, statistical estimation, pattern recognition, and many others (see Hall and Linn [7]). In addition, the fusion systems may use automated reasoning techniques to understand the context in which the entities are observed (i.e., situation assessment) and to understand the intent and possible threat posed by the observed entities (i.e., threat assessment).

Over the past two decades, significant DoD funding has been applied to the problem of data fusion systems, and a large number of prototype systems have been implemented (Hall, Linn, and Llinas [8]). The data fusion community has developed a data fusion process model [9], a data fusion lexicon [10], and engineering guidelines for system development [11]. While a significant amount of progress has been made (Hall and Llinas [12,3]), much work remains to be done. Hall and Garga [13], for example, identified a number of pitfalls or problem areas in implementing data fusion systems. Hall and Llinas [14] described some shortcomings in the use of data fusion systems to support individual soldiers, and M. J. Hall, S. A. Hall and Tate [15] discuss issues related to the effectiveness of human-computer interfaces for data fusion systems.

This paper provides a summary of current progress in multisensor data fusion and identifies areas in which additional research is needed. In addition, the paper describes some issues in the current state of practice of data fusion systems.
2. The JDL Data Fusion Process Model

In order to make this paper self-contained, we provide here a brief summary of the Joint Directors of Laboratories (JDL) data fusion process model [9,2,3]. A top-level view of the model is illustrated in Figure 1, and a summary of the processes is shown in Figure 2. This model is commonly used in the data fusion community to assist communications concerning data fusion algorithms, systems, and research issues. It will be used here for the same purpose.

![Figure 1. Top-Level View of the JDL Data Fusion Process Model](image)

The JDL model is a two layer hierarchical model that identifies fusion processes, processing functions and processing techniques to accomplish the functions. The model was intended for communications among data fusion researchers and implementation engineers, rather than a prescription for implementing a fusion system or an exhaustive enumeration of fusion functions and techniques. The model has evolved since its original exposition to the data fusion community. Steinberg and Bowman [17], for example, have recommended the inclusion of a new Level zero processing to account for processing such as pre-detection fusion and coherent signal processing of multi-sensor data. In addition, they suggest a re-naming and re-interpretation of the Level 2 and Level 3 processes to focus on understanding the external world environment (rather than a military-oriented situation and threat focus). C. Morefield [18] has suggested that the distinction between Level 2 and Level 3 is artificial, and that these processes should be considered as a single process. Bowman has suggested that the JDL model can be detrimental to communications if systems engineers focus on the model rather than a systematic architecture analysis and decomposition approach. Many of these comments have merit. However, for the purpose of this paper we will utilize the JDL model for describing the current state of practice and limitations.