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Exploitation of a priori knowledge for information fusion

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Abstract

The Information Fusion (IF) process is becoming increasingly more sophisticated, particularly through the incorporation of methods for high-level reasoning when applied to the situation analysis domain. A fundamental component of the IF process is a database (or databases) containing a priori knowledge that lists expected objects, behaviors of objects, and relationships between objects as well as all the possible attributes that can be inferred from measurements coming from a given sensor suite. We first present the basic concept of an existing support database (consisting of more than 2200 platforms) for Identity information fusion, and discuss its extension for higher-level fusion (e.g. situation and threat assessment). The database contains all the salient features needed for refining the identity of any target by the fusion of sensor information, and for addressing the situation and threat posed by groups of objects. The database is especially well suited for use in a Dempster–Shafer evidential reasoning scheme although it can also be used with Bayesian reasoning, if a priori probability distributions are known. Convincing results on several realistic scenarios of Maritime Air Area Operations and Direct Fleet Support are presented. This paper then develops the advanced concept of a Knowledge Management and Exploitation Server (KNOWMES) to support the IF process, through the use of ontologies and heterogeneous knowledge sources, which are necessary for higher level fusion.

Keywords: Platform database; Identity information fusion; Knowledge server

1. Introduction

Situation Awareness (SAW), a *state* in the mind of a human, is essential for commanders to conduct decision-making (DM) activities. It is about the perception of the elements in the environment, the comprehension of their meaning, and the projection of their status in the near future [1]. Situation Analysis (SA) [2] is defined as a *process*, the examination of a situation, its elements, and their relations, to provide and maintain a product, i.e. a *state* of SAW for the decision maker. Data/information fusion is clearly a key enabler for SA. According to Steinberg et al. [3], in their revision of the model proposed by the JDL sub-panel, data fusion is the process of combining data to refine state estimates and predictions.

The Information Fusion (IF) techniques being developed to support SA are becoming increasingly more sophisticated, particularly through the incorporation of methods for high-level reasoning processes. A fundamental component of these processes is a database (or databases) containing a priori knowledge that lists expected objects, behaviors of objects, and relationships between objects.

A priori knowledge contains static (or slowly changing) information/knowledge to support the various processes providing the decision-maker a higher level of

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situation awareness. In a military context, it refers to different aspects such as political and geographical knowledge, platforms characteristics, mission guidelines, weapon characteristics, corridors and flight paths, lethality, emitter characteristics, doctrine, etc., that can be used by the information fusion modules.

The choices made for the design and composition of the databases can therefore be an important factor in the usefulness of the IF processes that they support. These choices can also potentially impose critical analysis bottlenecks in the processes, and ultimately, they can even represent significant barriers to enhancing these processes.

The expression "a priori knowledge" entails several things. The "knowledge" portion of the expression refers to the fact that the database may contain more than just a description of objects. More abstract notions about the behavior of these objects, or the relationships between objects can also be included. It is the existence of this different level of information, so important to sophisticated IF processes, that characterizes the database as containing knowledge, not simply data.

The "a priori" portion of the expression entails that the contents of the database are mostly collected, analyzed and stored in advance of use in the IF processes and also in the overall Decision Support System. However, aspects like user modification of the database, or intelligent learning agents that can dynamically add knowledge to the database, also need to be considered.

The paper starts by presenting the basic concept of a support database (consisting of more than 2200 platforms). The database contains all the salient features needed for refining the identity of any target by the fusion of sensor information. The database is especially well suited for use in a Dempster–Shafer evidential reasoning scheme although it can also be used with Bayesian reasoning, if a priori probability distributions are known. Examples of its usage are given on realistic scenarios of Maritime Air Area Operations (MAAO) and of Direct Fleet Support (DFS). The paper then describes an advanced concept of a knowledge server that makes use of ontologies and heterogeneous knowledge sources useful to the IF process, that could incorporate the support database.

2. Support databases for identity information fusion

2.1. An identity information fusion process

The purpose of a Multi-Source Data Fusion (MSDF) system is to produce an estimate of the position and identification of all objects of interest within a given context. In a military context, MSDF deals with the alignment, association or correlation, filtering and combination of data and information obtained from multiple sources to achieve refined state and identity estimation for each target present in the operational environment. As shown in Fig. 1, an MSDF system can be broken into several pieces: input data preparation, system track selection, data alignment, data association, cluster management, kinematics information fusion, Identity Information Fusion (IIF), track management, configuration monitoring and control, and internal system track data store (ISTDS). These pieces operate in a well-orchestrated manner to map the source data onto the ISTDS. It is assumed implicitly that the input data preparation can contain such procedures as track-before-detect in low signal-to-noise ratios regimes.

In this paper, the emphasis is on the target IIF process that is an important process to achieve situation awareness. The IIF process involves the items indicated

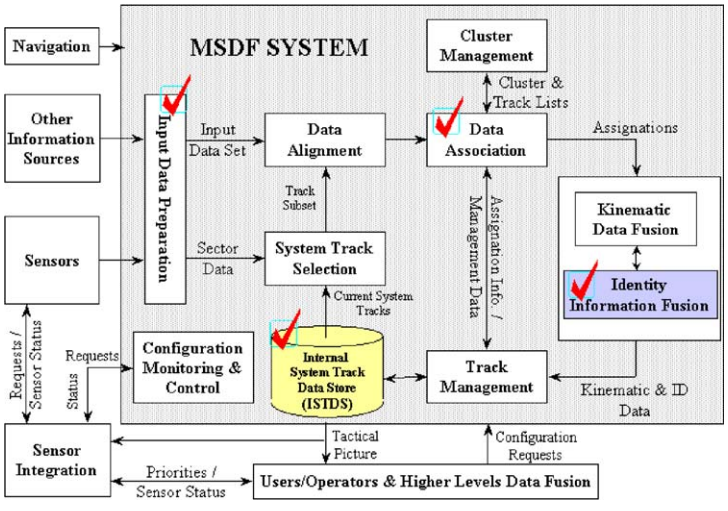

Fig. 1. A multi-source data fusion system (could be an example of SAAP in Fig. 9).