

장소인식멀티센서스마트 환경을위한 데이터 퓨전 모델

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Locality Aware Multi-Sensor Data Fusion Model for Smart Environments

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Abstract

In the area of data fusion, dealing with heterogeneous data sources, numerous models have been proposed in last three decades to facilitate different application domains i.e. Department of Defense (DoD), monitoring of complex machinery, medical diagnosis and smart buildings. All of these models shared the theme of multiple levels processing to get more reliable and accurate information. In this paper, we consider five most widely acceptable fusion models (Intelligence Cycle, Joint Directors of Laboratories, Boyd control, Waterfall, Omnibus) applied to different areas for data fusion. When they are exposed to a real scenario, where large dataset from heterogeneous sources is utilize for object monitoring, then it may leads us to non-efficient and unreliable information for decision making. The proposed variation works better in terms of time and accuracy due to prior data diminution.

1. Introduction

In last three decades, multi-sensor data fusion has established considerable attention for both military and non-military applications. The heterogeneous data received from multiple sensors get combined or integrated using some related information to attain superior accuracies and more relevant inferences than could be achieved by utilizing a single sensor [1]—[4].

The conception of multi-sensor data fusion is not new. Naturally, humans and animals have evolved the aptitude to exploit multiple senses to improve their survival ability in this world. To build a better understanding about this phenomenon, we consider a scenario. For example, it may not be feasible to judge the quality of an edible substance based exclusively on the sense of touch or vision, but assessment of edibility may be easily accomplished using a combination of touch, taste, sight, and smell. Similarly, while one is incapable to observe around comers or through vegetation, the sense of hearing can provide sophisticated warning of imminent dangers. Thus, process of fusion based on multi-sensors is naturally performed by animals and humans to attain more precise assessment of the surrounding environment and identification of threats, thereby leads to their improved survival.

It is the fact that data fusion models profoundly depend on the application, so no commonly accepted model be present for fusion. Kam, Zhu, and Kalatak accordingly stated in [5], it is implausible that one technique will provide a consistently better-quality solution. Thus, there exist various models for data fusion in the literature. So before using fusion mechanism in an application, it is of interest which

model can be exploited as a design pattern.

Multi-sensor data fusion has been incorporated in extensive applications. Military applications comprise: auto-target recognition (e.g. for smart weapons), assistance for self-directed or independent vehicles, battle-field, remote sensing, surveillance, and identification-friend-foe-neutral (IFFN) systems [6] which comes under the category of Automated Threat Recognition Systems (ATRS). Monitoring of manufacturing processes, condition-based maintenance of complex machinery, robotics [7], and medical are non-military applications areas. Techniques to combine or fuse data are drained from a diverse set of more traditional disciplines including: artificial intelligent (AI), statistical estimation, digital signal processing (DSP), control theory, and typical numerical methods [8]—[10]. Historically, data fusion methods were developed primarily for military applications. However, in recent years these methods have been applied to civilian applications as well like in health care systems (HCS).

In this paper, we have devised a variation to few well known existing fusion models for improvement with respect to time and efficiency. The beauty of this suggestion is that it can be incorporated to any existing fusion model without harming its effectiveness.

The rest of the paper is organized as follows: at the beginning of Section 2 the conceptual explanation of different fusion paradigms has been given to clarify the context; later on brief description about few well known existing fusion models have been explained. The proposed deviation is slightly highlighted in next section, and conclusion is contained in Section 4 prior to the acknowledgement and References.

2. Paradigms

Many forms have been taken for conceptual organization of our assembled knowledge regarding data fusion. In accordance with that we may come up with some terminology confusions. Therefore, we have decided to have prior knowledge about key terms which can elaborate the means of fusion based algorithms under the umbrella of huge systems.

Currently core organizational paradigms (Architectures, Frameworks and Models) which are in use for unfolding data fusion systems. Each of them is briefly described in the subsequent paragraphs or subsections in chronological order to have better understanding about their relationship with the current context.

2.1 Architectures

Architecture can be defined as a tangible structure of the whole system more precisely it can be referenced as a communication approach for useful data or information. From it we can extract answers to following questions, like:

- How different component parts should be arranged?
- How communications among them will be done?
- More importantly their data or information flow strategy?

Any physical structure, by fulfilling above mentioned criteria, can deserve to be architecture. It is a high level sketch for data fusion systems, which can be elaborated as non-distributed or centralized based on their architectures. Specifically it can be a blackboard system [11] and *common object request broker* (CORBA) [12] which belongs to distributed architectures.

2.2 Frameworks

A framework can be easily defined as a collection of truisms and reckoning system for maneuver entities based on those platitudes. It can be used to extract meaningful information from a raw-data. Evidential and probabilistic reasoning systems are good examples of a framework.

2.3 Models

We define a model, more precisely a process model, which can be depicted as a bunch of processes. A system can't be fully operational until processes are undertaken. It just highlights the functionality of the component parts without emphasizing on their soft or hard instantiation. Even though architectures and frameworks are equally likely important but this paper critically deals with few existing process models and to suggest a new model based on some specific criteria or context.

Numerous data fusion models have been proposed both within the research community and commercial environments. These models provide an aiding facility to plentiful projects in development of fusion system by incorporating most appropriate strategy for distinct problem.

Fusion model has its roots in early 1980sf when defense research community introduced early fusion models for military purposes. The use of data fusion has broadened to include industrial, commercial and medical applications.

Most up to date models has reduced military terminologies at some extent but not completely. In this section, we briefly analyzed few most prominent fusion models:

2.3.1 Joint Directors of Laboratories (JDL)

One of the most extensively used models in defense area is Joint Directors of Laboratories (JDL) fusion model. In the early years of data fusion, this model was developed by US department of defense to aid the developments in military applications. Llinas et al. [14] has given its description in terms of hierarchy/levels object refinement, situation assessment, threat analysis, and process refinement.

Level 1, object refinement, deals with the raw data to extract some basic level information like object's position, velocity, identity etc. A global picture of the situation is acquired at this stage.

Level 2, situation assessment, finds a relationship of the information extracted at level 1 to current scenario or events (e.g. Object is moving in a specific area).

Level 3, threat analysis, finally analyze the overall situation in terms of consequences of their final decision.

Level 4, refinement module get an eye over all other modules to observe performance, highlight potential sources of information enhancement, and optimize sensors allocation process.

2.3.2 Circular Intelligence (CI)

They portray intelligence process in a circular model [13]. The beauty of this intellectual cycle is to process and fuse information collectively. It comprises of assortment, collation, assessment and propagation stages.

At first stage, assortment, all the required raw data from different sources (sensors or human derived) is deployed to retrieve some associate intelligence. Collation identifies the correlation mechanism to be utilized in later stages. The collated data or reports get fused on the basis of some intellectual criteria in the assessment stage. And finally the results or outcome is broadcasted to concerned parties for final decision or action.

2.3.3 The Boyd Control Loop (BCL)

The Boyd control loop model [15] was utilized exclusively for military command processing but later on incorporated in non-military applications areas. Information fusion took place in four stages using this model. The objective of the observation stage is used to gather required data from the environments based on the heterogeneous sensors and sources. Once data is collected, it relates the data with the current scenario, in other words its functionality is similar to JDL model's level 2 processing. Third stage deals with the decision on the basis of the analysis performed at second stage. Its behavior is quite similar to JDL's level 4.

2.3.4 The Waterfall Model

In [16], the UK researchers introduce the concept waterfall model for emphasizing on the lower level functionality. Most of the functionality is similar to JDL model but do not provide any feedback mechanism to the sensors or other sources which is its major limitation. On the

other hand its fusion mechanism is smooth as compared to other existing methods. It has also been widely used in UK defense community and got popularity there.

2.3.5 Omnibus Model

To overcome the deficiencies of the above mentioned models a new unified model, Omnibus model [17], was proposed to combine the strengths of two existing fusion models namely Boyd Loop and Waterfall model. It incorporated the subdivision property of the overall system, and secondly the reusability of the structure has strengthened their functional objectives.

3. Locality Aware Multi-Sensor Data Fusion Model

In this paper, we have considered five different data fusion models to analyze the feasibility of our proposed model. In this model we have incorporated the locality mechanism in the whole fusion model as shown in Figure 1.

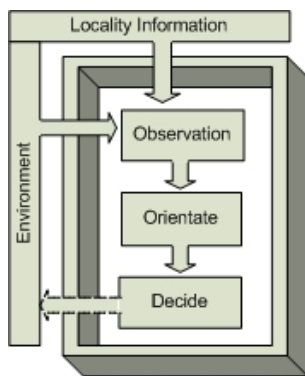


Figure 1: Block Diagram of Locality Aware Data Fusion Model

In a smart environment, information about concerned activities is acquired through some sophisticated heterogeneous sensors or from other data sources. All the existing models just consider whole data from every sensor for further processing. In our case, we filter out raw data or information at every level of the fusion process. This is the key advantage over all existing methodologies.

At first level, raw data fusion, we will consider those sensor's data which will be more relevant or closer to the object being monitored. Similarly, for later stages we will incorporate locality information of the object to infer higher or more abstract level information.

4. Conclusion

The key shortcoming of existing data fusion models is that they are specifically slanting towards a military domain (to some extent). Due to extensive usability of the fusion models in commercial and industrial problems, it is necessary to define a model which can be easily adoptable to specific area without compromising on performance and effectiveness. In this paper, we have devised a mechanism at lower level of data fusion model through which we can attain higher efficiency by reducing the complexity of the raw data. In this model we have retained all the strengths of the Waterfall and Boyd Loop models. It can be utilized efficiently in real

(online, means runtime data acquisition and response) and non-real (offline, data received from a huge size repository get processed) applications area. The taxonomy used is slackly based on existing notation to maximize ease but moves away from a defense-based system.

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