Chapter 6
Inference Degradation in Information Fusion: A Bayesian Network Case

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ABSTRACT
Dynamic and active information fusion processes select the best sensor based on expected utility calculation in order to integrate the evidences acquires both accurately and timely. However, inference degradation happens when the same/similar sensors are selected repeatedly over time if the selection strategy is not well designed that considers the history of sensor engagement. This phenomenon decreases fusion accuracy and efficiency, in direct conflict to the objective of information integration with multiple sensors. This chapter tries to provide a mathematical scrutiny of this problem in the myopia planning popularly utilized in active information fusion. In evaluation it first introduces the common active information fusion context using security surveillance applications. It then examines the generic dynamic Bayesian network model for a mental state recognition task and analyzes experimentation results for the inference degradation. It also discusses the candidate solutions with some preliminary results. The inference degradation problem is not limited to the discussed task and may emerge in variants of sensor planning strategies even with more global optimization approach. This study provides common guidelines in information integration applications for information awareness and intelligent decision.

INTRODUCTION
Data and information becomes very rich if not overwhelming in many modern applications, such as real-time driving assistance systems that integrate information from the sensors installed at different locations of a vehicle, or military C3I systems that make critical decisions based on efficient command and intelligence processing in complex battlefield. The 911 tragedy asks for essential security applications such as event surveillance and detection, intelligence monitoring and analysis, intrusion and deception detection, as well as their implementations in terrorism tracking, analysis, and response.

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Within various research fields, knowledge discovery and integration algorithms can lead to efficient solutions to assist model integration and decision making in complex and distributed environment. With so much information in hand in such applications, a suitable strategy that must apply intelligent and active information fusion is the key enabling technique.

Information fusion/integration aims at combining multiple evidences, which normally contain overlapping (correlating) information relating to the underlying hypothesis due to the generating mechanism of these evidences, in order to gain better accuracy or higher confidence on information of interest (Hall & McMullen, 2004; Klein, 2004). Thus any algorithm that takes multiple inputs to evaluate a target output can be candidates for information fusion. The main challenges in information fusion include uncertainty and incompleteness in evidence, requirement on processing speed and cost, etc.

In this article, we set the knowledge discovery and integration task used in discussion and experimentation to be human subject modeling. Such a model integrates video and acoustic information of human subjects as well as other related contextual information, and infer about the internal status about the subject’s mental and emotional aspects. This internal status can provide information of significant safety and security interests. Moreover the model could be about not only individuals but also a crowd of people. Through certain active strategy, it generates in a timely manner important indicators such as anxiety and stability of an individual or a crowd, which are useful measures of danger level of a special event involving human participants. Based on the given information, further analysis could be done with the help of other information such as the interacting machinery like a car or a fighter aircraft, or identification of the subject and report about possible terrorist plot, leading to proactive procedures of warning and countermeasures. Therefore such a human subject model can in fact function as a core component of intelligent assistance in battlefields, or scene surveillance and analysis in homeland security settings, providing real-time support for efficient decision making in emergency response and control.

Machine learning, artificial intelligence and psychological models have been extensively used in the information fusion in user modeling or human mental state detection (Cohen et al, 2000; Duric et al, 2002; Horvitz et al, 1998; Hudlicka & McHeese, 2002; Jameson, 1996; Picard, 1997; Salvucci et al, 2001). Of them, Bayesian network (BN) models have been applied in many user modeling and information fusion applications because of the capability to handle uncertainty and the analogy to human reasoning process, exemplified in a set of studies of intelligent office software assistants in the Lumiere Project other studies by Microsoft (Horvitz et al, 1998; Horvitz & Paek, 1999, 2000) and studies in affective state detection (Ball & Breese, 2000; Conti, 2002). In addition there are a range of information fusion applications for Bayesian networks, such as security modeling for service and health enterprise (Li et al, 2009; Li & Chandra, 2008).

Although the computing power increases with the development of new computer technology, the complexity and rapid growth of the size of problem space often require a supervised selective sensory strategy to acquire and integrate the most significant evidence. Therefore active fusion strategies based on information entropy and utility theories have been proposed to respond to the challenge of constraints in terms of Bayesian inference in information processing and sensory cost in information acquisition (Horvitz et al, 1998; Li & Ji, 2005). However, if not carefully designed and implemented, as we will discuss here and show in the experimentation, such active strategy is prone to select the same set of sensors again and again. This can lead to the reduction in inference capability for accurate and timely belief updating. This is in direct confliction to the objective of multiple sensor fusion. We call the