

# Chapter 11

## Multisensor Integration and Data Fusion for Positioning

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### ABSTRACT

*This chapter presents an alternative framework to the traditional centralised Kalman filtering (CKF) approach for implementing the optimal state estimation algorithm in support of multisensor integration. The data fusion algorithm is implemented via a series of transformations of vectors in the so-called information space (iSpace). This chapter describes how the conventional decentralised Kalman filtering (DKF) algorithm can be derived using a unified approach. A new global optimal fusion (GOF) algorithm is derived using the iSpace approach. Two case studies are presented to illustrate applications of the multisensor algorithms for GNSS/Locata/INS and GNSS/WiFi/INS integration.*

### INTRODUCTION

To implement a practical multisensor navigation system, the challenges include, but are not limited to, the time-synchronisation of sensor outputs, communications in the sensor network, and computational load allocation for local and/or central processors. Nevertheless, the core technology for multisensory navigation integration is the algorithm, which combines the data from multiple sensors so as to obtain the optimal estimate of the states of the host platform. Some fundamental questions related to the optimal state estimation in multisensor systems include:

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- What information (e.g. the data from the sensors and apriori knowledge) can be used in the estimation?
- How to compare the accuracies of different algorithms? Which is the better criterion for multisensor data fusion, the centralised Kalman filter (CKF) or the two-level optimal criterion?
- Is it necessary to develop a unified theoretical framework to deal with the multisensor data fusion problem?
- Does the framework provide a means for understanding multisensor data fusion as well as conventional optimal estimations?

The conventional approach for optimal estimation of a multisensor system is the centralised Kalman filtering approach, which, as the name implies, processes all sensor measurements at a central processor. CKF has some inherent defects, such as heavy computational load and poor fault-tolerant capability. To deal with the above shortcomings, decentralised Kalman filtering (DKF) methods have been developed for applications such as distributed control systems and integrated navigation. A typical DKF configuration is a spider-net style sensor network, in which a processor at the centre of the network is used to manage all sensor nodes. Each node consists of the sensor and its accompanying local processor. The local estimates are sent to the central processor where they are fused to obtain the globally optimal estimate (Hashemipour *et al* 1988).

Data fusion techniques can also be applied for target tracking applications, and are classified either as low-level “scan” fusion or high-level “track-to-track” fusion, which are achieved by combining observations from different sensors and combining estimates from sensor sites, respectively. Similar to the DKF in multisensor navigation applications, the advantages of easy fault detection and low computational load make the track-to-track fusion architecture a popular choice. The key issue for track-to-track fusion is strong correlation between the tracks because they have a common prediction error resulting from a common process model (Bar-Shalom 1981). Systems that ignore such correlation would be expected to have poor performance. Many methods have been developed to address the correlation problem (Bar-Shalom 1981; Aeberhard *et al* 2012). However such methods still cannot achieve better performance than the low-level “scan” fusion method.

To address the fundamental questions listed above, a new framework was recently developed for multisensor integration, which provides a unified approach to derive the multisensor fusion algorithms using the information space approach (Li 2014). The optimal fusion is implemented by a series of transformations between the information spaces (*i*Spaces). The transformations map the source information vectors from the measurement *i*Spaces to the estimate *i*Space to generate the fused information vector. The *i*Space approach provides a means by which the accuracies of different algorithms can be compared on the same theoretical basis. In fact there are multiple sources of information available for estimation in a multisensor system. An algorithm can use either some or all of the information resources to derive the solution, and therefore algorithms using different source information will have different estimation accuracies although they all are optimal in terms of their own *i*Spaces. From this point of view the CKF is no longer necessarily superior to other algorithms. It is just one of the optimal fusion algorithms in the *i*Space framework instead of providing the global optimality criterion of the multisensor data fusion.

During the past few decades many positioning and navigation systems and technologies have been developed to address a variety of user requirements under different application environments. The Global Navigation Satellite System (GNSS) technology is able to provide accurate position, velocity and time data, on a 24/7 basis, without any impact of mission length or time since update. However it is most effec-

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