From the Editor-In-Chief

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Where Are the Design Methods for Information Fusion Algorithms?

The community of information fusion researchers is a very prolific group that publishes papers in numerous annual conferences and journals. However, the number of success stories associated with fielding systems that include information fusion is relatively small. When considering the low rate of transitions of information fusion techniques to real-world systems, I noticed that for all practical purposes no design methods exist for information fusion algorithms. Since engineers, not researchers, design and build systems, tools and design processes for design engineers are critical to the implementation of information fusion methods in real-world systems.

According to the Accreditation Board for Engineering and Technology (ABET), engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. This ABET guidance implies a design process that achieves a guaranteed performance. The technical domain of information fusion includes very little for which engineers can draw upon in their design process and almost none of the information fusion algorithms have any performance guarantees for which the designer can utilize to ensure the needs of the design will be met the needs or requirements. In this editorial, I focus on the need for design processes, while system requirements and performance guarantees will be discussed in the June 2012 editorial.

Until recently [1, 2], the wealth of literature on the well-studied and rather straightforward problem of tracking maneuvering targets did not include design methods. The model mismatch present in the Kalman filter (zero-mean white process noise) to model (deterministic but unknown) target maneuvers complicates the design process, and the lack of attention from the information fusion community on a design method has left this as an open problem for over 30 years. Prior to [1, 2], conventional wisdom for the design of nearly-constant filters for tracking maneuvering targets [3] suggests that the process noise standard deviation should be chosen greater than one half the maximum acceleration of the target and less than the maximum acceleration. This guidance was based on experience and the design criterion was never quantified. In fact, using this design guidance can lead one to design a track filter that produces errors greater than the errors in the sensor measurements [4]. In [1, 2], the maximum acceleration of the target and duration of the maneuvers along with the sensor parameters were used to define upper and lower limits on the process noise standard deviation. The lower limit on the process noise standard deviation is defined to prevent the estimation errors from exceeding the measurement errors, while the upper limit is set to minimize the maximum mean squared error. Thus, a systematic method for the design of nearly constant velocity filters for tracking maneuvering targets is introduced in [1, 2]. That technique is extended to radar tracking in [5].

This problem of tracking maneuvering targets has more open issues with respect to design methods. For example, the choice between a nearly constant acceleration filter and a nearly constant velocity filter for a specific tracking problem is an open issue. The choice between a multiple model estimator and a Kalman filter is another open issue that was originally addressed in [6]. A shortcoming of the results in [6] is the need to select the process noise standard deviation which we know was an open issue during its publication. The technical domain of information fusion is full of open problems related to the design of information fusion algorithms. Some examples include selection of the gating threshold, choice between probabilistic data association and multiple hypothesis tracking (MHT), selection of the memory depth of an MHT, and selection of the costs of missed detections and no assignment in measurement-to-track assignment.

Development of effective design methods for information fusion algorithms is the next frontier for the information fusion community. Every implementation of information fusion cannot be treated as a new research problem, if information fusion algorithms are going to be implemented in real-world systems. Readily available design methods with performance guarantees are a prerequisite for the transition of information fusion methods into real-world systems. Development of design methods needs to become the newest research topic for the information fusion community.

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