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Introduction

This was the 24th in a series of SPIE conferences to focus on signal and data processing of small targets. Most SPIE conferences are concerned with processing large targets, namely, targets large enough for traditional automatic (or assisted) target recognition (ATR) with a single frame of data. A 2-D target large enough for ATR is typically larger than 100 resolution elements, for example, larger than 10 by 10 pixels. In contrast, this conference series introduced a different thrust for SPIE in 1989: processing targets smaller than 100 pixels.

This year the conference was held in Baltimore after being held in San Diego the prior year. In the future, these conferences are expected to be located in Baltimore in the spring on *even* years but continue to be in San Diego in the summer on *odd* years. The proceedings of the prior conferences in this series in 1989 through 2011 are SPIE Volumes 1096, 1305, 1481, 1698, 1954, 2235, 2561, 2759, 3163, 3373, 3809, 4048, 4473, 4728, 5204, 5428, 5913, 6236, 6699, 6969, 7445, 7698, and 8137. A compact disk of all the papers in this series from 1989 through 2000 is available from SPIE; it is Volume 20, which is a two-disk set.

The various types of processing tasks with sensor-derived data of targets can be broadly categorized into four generic classes, as follows:

- Sensor tracking of a single (bright) target
- Image and data processing of large targets
- Signal and data processing of medium sized targets
- Signal and data processing of small targets.

Note that the size indicated in this list is in terms of the number of resolution elements or pixels. The motivation for categorizing the processing of sensor data this way is because most of the appropriate algorithms for each of these problems differ substantially from that of the others. This conference concentrates on small targets that include:

- Point source objects
- Small-extended objects
- Clusters of point source and small-extended objects or threat clouds, such as Chem/Bio threats.

The size of a typical point source target in the field of view is from less than one to about 20 pixels (resolution elements) wide, depending on the sensor design. Although the processing of point targets with data from a single sensor has been studied extensively, there are still many interesting challenges in this field. In contrast, the state of the art of sensor data fusion and for processing small extended-objects, clusters, and Chem/Bio clouds is far less mature, but interest is growing. The topic of Chem/Bio has been added to this conference series because the methods for tracking clusters of objects and tracking of small extended-objects may be applicable with modification. Similarly, the topic of processing for defense against cyber threats has been added because the processing methods developed for target tracking may be helpful in the cyber domain.

Small targets that are not point source objects include dismounts, small-extended objects, and unresolved closely spaced objects, sometimes called clumps. While these small targets provide little detailed information useful for ATR, they do exhibit some shape and size information that might be useful in tracking. In addition, an extended object may at times be partially or fully obscured or may obscure rather than add to the background. The apparent size and shape of a target can differ from sensor-to-sensor and over time; this may have to be taken into account. Similarly, cluster and Chem/Bio processing offers significant advantages and unique challenges since they can change in size, shape, and orientation as well as motion.

Current algorithm development is driven by new or improved sensors, increasingly demanding system requirements, efficacious countermeasures, severe operating environments, processor hardware limitations, new innovative processing methods, and challenging threat scenarios. Of special interest is the ability to track low observables or in a moderate to dense population of threshold exceedances caused by clutter, false signals, or targets that are close or crossing along with the limitation in sensor resolution.

Note that the process of algorithm development is emphasized here because Monte Carlo simulations are needed to obtain functional performance of tracking with confidence. Tracking functional performance is not amenable to mathematical analysis because it depends on random variables from both continuous sample space and discrete sample space. This property makes algorithm design, performance evaluation, and the entire algorithm development process complex and challenging. No surprise that performance results can initially appear counter intuitive.

There is an increasing need for improvements in "algorithm efficiency," i.e., improved performance relative to the processor and communication resources required. A major trade in selecting algorithms for processing small targets is performance versus required processor and communications capacity. Also needed are accurate evaluations and predictions of required resources and functional performance under realistic conditions. Major improvements are needed in: multiple target tracking, network centric sensor data fusion, multiple frame data association, multiple frame signal processing (such as track-before-detect), effective management of sensors, communications, and processor resources, MHT methods use in cyber domain, target classification/typing, processing of features and attributes, efficient signal processing and tracking of Bio/Chem clouds, adaptive tracking, and the interaction between signal processing and tracking. Many of these issues are highlighted in Figure 1. In addition, there is a need for an indication of track quality and related information in the tracker output to the users and functions that depend on the tracker data to facilitate the improvement of their performance.

The term *fuse-before-detect* in Figure 1 refers to the combining (fusing) of raw data from multiple sensors before finalizing detection at the signal processing level. I coined this term in recognition of the increased interest in improving performance by fusing sensor data early in the processing chain. Note also in Figure 1 the possible use of track data at the signal processing level. There is a growing recognition of the importance of using all available information in every stage of the processing and hence the use of feedback.

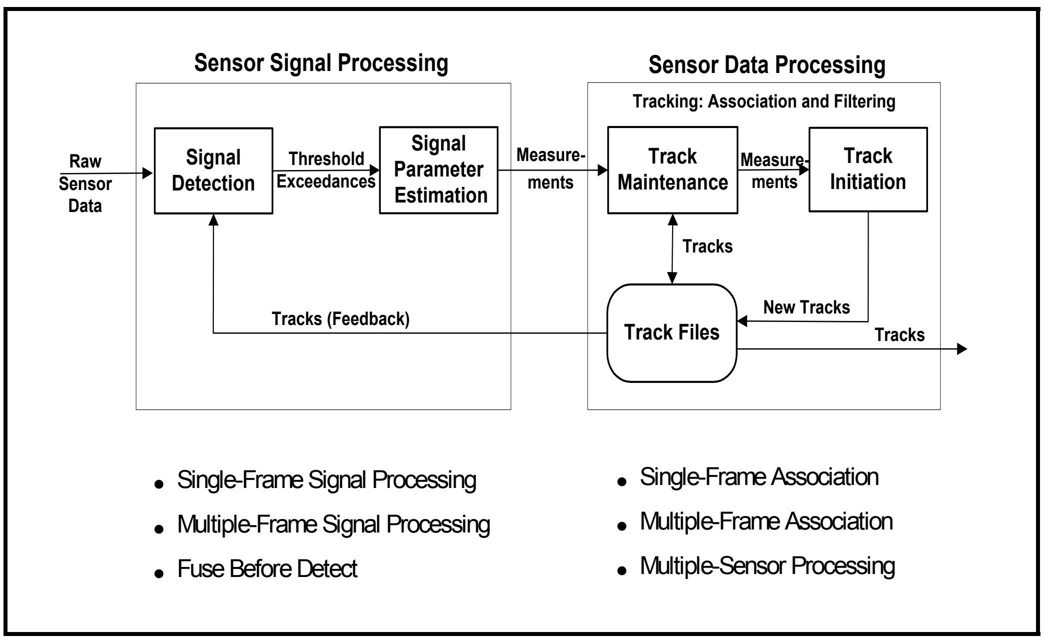

Figure 1. Sensor Signal and Data Processing

This conference has provided a forum to address these issues through discussion of algorithms and simulations for digital signal processing, target tracking, and sensor data fusion under challenging conditions, i.e., data association (correlation) and filtering, including related data processing, such as system resource management, and target classification/typing. Of the four half-day sessions, one addressed signal-level processing including Chem/Bio cloud processing, two addressed target tracking and related functions, and one addressed sensor data fusion including network wide processing. The distinction between the two stages of single sensor-level processing is shown in Figure 1.

These proceedings papers contain a wealth of information that address the issues critical to practical processing under the challenging conditions outlined above. For example, important advances were presented in: processing Chem/Bio sensor data, filter methods to accommodate non-linearities, alternative multiple frame data association, improved distributed sensor data fusion, processing data of dismounts, reducing track coalescence, high fidelity simulations, and processing target features/attributes. These techniques and others presented are strong candidates to permit high performance target tracking and sensor data fusion plus related processing of low observables or in an environment of moderately dense detections and with abruptly maneuvering targets. These and other innovative yet practical techniques were presented that contribute to improving algorithm efficiency for processing small targets.

Many of the experts and organizations that are making the major important advances in practical sensor signal and data processing have contributed to these proceedings. We thank the authors, session chairs, attendees, and SPIE coordinators for making the three-day conference such a success. They have taken part in enthusiastic discussions that generated better understanding for the application of the techniques presented and have stimulated thoughts for further improvements. Informal discussions during the coffee breaks and the poster session were especially productive, as usual. With these proceedings, the authors have extended the state of the art of analysis, algorithms, and simulations for the use of data from one or more sensors used in signal and data processing of small targets and related processing.

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