MAS 08 Optimum Joint Event and Parameter Estimation in SN Based on Random Set Theory

MAS 08.1 Overview

In SN, for dynamic events, classical joint estimation/detection/tracking multi-sensor and multi-target algorithms are often hybrids of both analytical and ad-hoc approaches at various levels. The intricacies of the resulting solutions when the number of targets and sensors may vary randomly often obscure design intuition and leave many design choices to a largely trial and error based approach. Random Set Theory is a formal generalization of the classical random variable into the random set domain.

MAS 08.2 Approach

By treating multi-target and multi-sensor jointly, RST is able to provide a systematic framework for rigorous mathematical analysis. Because of its set theory domain, RST is able to model the randomness of transmission noise, missed detection, sensor failure, target appearance and disappearance, clutter, jammer, ambiguous measurements, and other practical artifacts within its probabilistic framework. Furthermore, a rigorous statistical framework has been developed for RST that includes concepts as: ML, Bayesian filtering, data fusion, and Creamer-Rao Bound.

MAS 08.3 System(s) Description and/or Experiments

We initiated a proof-of-concept use of RST to jointly detect/locate/track targets successfully in a simple power aware spatially dense uniform grid WSN setting. Consider a simple model using a large number of low cost sensors placed in a uniform grid field, in which when each sensor is activated, it sends the detected signal strength of the source within its limited sensing range, using its radio to a fusion center for processing. Due to a sensor's limited sensing range, we can assume a sensor is only activated by a single source, while there may be other sources in the entire field. Most sensors are in the "sleep mode", capable of detection but not transmission. In this model, there are at least three kinds of randomness in the system. First, there is the conventional random noise in the radio transmission channel of each sensor. Second, the number of sources (i.e., targets) in the field may also be random (since non-static sources may enter and leave the field in an unknown manner). Third, the number of sensors actually able to sense and perform a successful radio report may also be random, due to battery or circuit failures, or severe propagation losses. The systematic treatment of the last two kinds of randomness, which is intrinsic to a WSN, should not be performed in an ad hoc manner, but should best be handled using RST.

MAS 08.4 Accomplishments

Consider a WSN scenario, where we deploy 100 sensors distributed on a 100 by 100 meter square field in a uniform grid. When a target is present, it emits signal power P_0 that decays $r^{-\alpha}$, where $1 < \alpha \leq 2$. Each sensor will receive this signal that gets corrupted by an AWGN with variance σ^2. If the received signal is above the threshold τ, the sensor reports its reading to the fusion center. At each time instant, the fusion center jointly detects whether there is a target, and when there is one, estimates or even tracks its position. In Figure 1-a, we show the tracking of a target moving across the field when all the sensors are working properly, while in Figure 1-b, some sensors have failed to report and the tracker is not aware of their failure. The resulting tracks (shown by the x symbols) are poor. In Figure 2-a, when the fusion center is running the RST tracking system, the failed sensor information are used automatically by the RST system, and the target tracking suffers momentarily. Figure 2-b shows under the RST operated system, future tracks recover properly. In Figure 3-a, the RFS fusion center tracks a target for 11 time instants. Then it

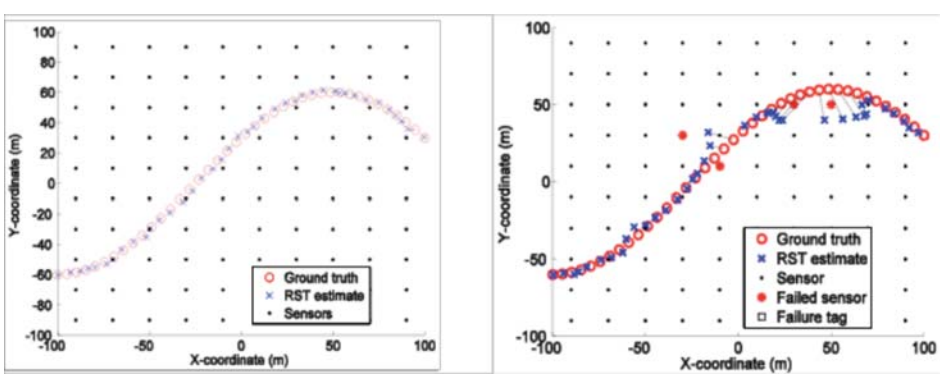

Figure 1. Left. All sensors operate properly. Right. Some sensors failed to report resulting in poor tracks.

disappeared from time 12 to 15, but a target reappears from time 16 to 31. The RST fusion center can re-initiate the tracks properly. In Figure 3-b, the RST tracker estimates only one source from time 1 to 15, zero source from time 12 to 15, and one source from time 16 to time 31.

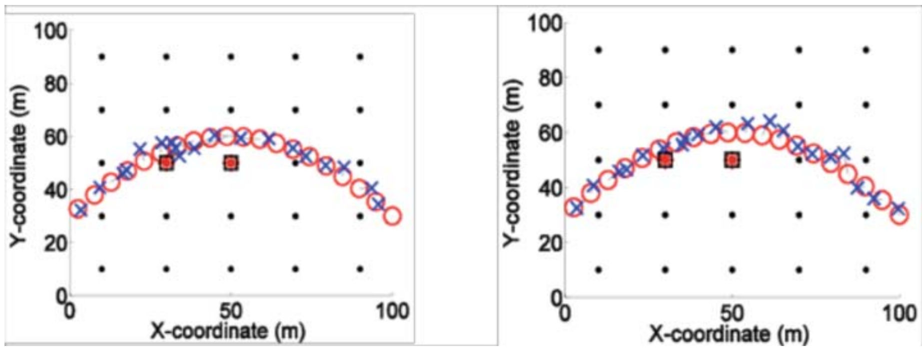

Figure 2. Left. Two sensors failures detected by the RST fusion center. Right. Future tracks recover properly.

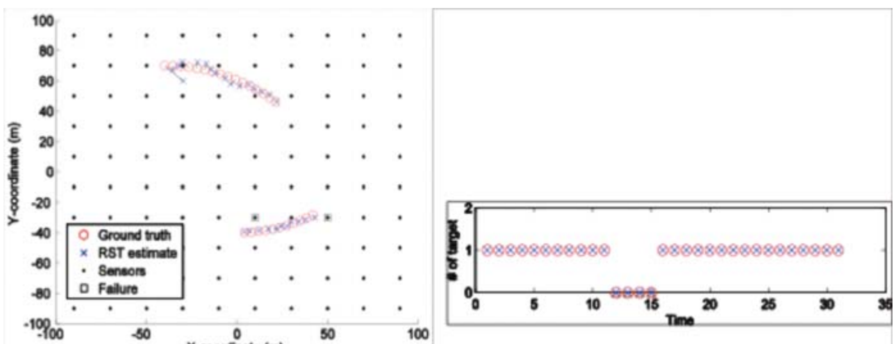

Figure 3. Left. RST fusion center tracking two targets. Right. RST tracker estimates one, zero, and then one target.

MAS 08.5 Future Directions

Passive acoustic tracking benefits animal bio-behavioral study in replacing or enhancing human involvement in performing field data collection. Multiple simultaneous vocalizations are a common occurrence in a forest or a jungle, where many species are encountered. Given a set of nodes that are capable of producing multiple direction-of-arrivals estimates, such data needs to be combined into meaningful tracks. RST provides the mathematical probabilistic model, which is suitable for analysis and optimal fusion center synthesis. Our proposed algorithm will be tested, modified (incorporating conceptual reformulations), and retested based on real life experimentally collected data.