University Defence Research Collaboration (UDRC)
Signal Processing in a Networked Battlespace

WP5: Networked enabled sensor management
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Introduction: The aim of this work package is to investigate the resolution of sensor management problems involving hierarchical information-based decisions at different levels of the signal processing chain (sensor modes and multi-sensor control policies). The general goal is to provide a unified framework for multi-object Bayesian filtering (i.e. multi-target detection and tracking), multi-sensor data fusion and sensor management. The Finite Set Statistics framework, developed for the construction of various multi-sensor/multi-target tracking filters following a principled approach, is flexible enough to incorporate sensor management policies into a unified framework and will be the backbone of the developments in this work package.

Objective:

WP 5.1: Hierarchical sensor management to target tracking (→ WP2, WP3)
- Unify multi-object Bayesian estimation, multi-sensor data fusion, and sensor management;
- Focus on novelty and clarity of proposed solutions.

WP 5.2: Computationally tractable solution (→ WP6)
- Improve the implementation and reduce the computational costs of the new algorithms;
- Focus on parallel processing, SMC/GM implementations, optimal allocation problems.

WP 5.3: Multi-objective sensor management
- Explore additional objectives beyond target detection/tracking;
- Focus on prioritisation of multiple objectives.

Multi-object Bayesian estimation

How many targets? Where are they?

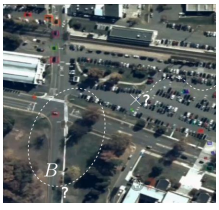
http://www.nollywoodone.com/latest-additions/9009-the-u-s-military-s-real-time-google-street-view-airborne-spy-camera-can-track-an-entire-city-in-1-800mp.html

Multi-object filters may propagate:

- Regional information on target activity (i.e. mean target number $\mu_\Phi(B)$);
- Individual information on specific targets (probability of existence, spatial distribution).

Stochastic population of objects modelled with *point processes* or *Random Finite Sets*:

- Target population;
- Target interactions;
- Target measurements;
- Missed detections;
- False alarms;
- Target appearing/disappearing;
- ...



Estimation of regional activity

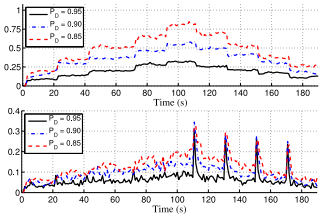


Figure 1: Variance in target number: PHD filter (top), CPHD filter (bottom)

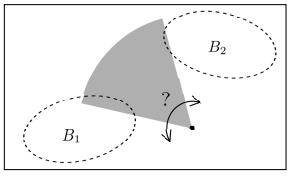
Statistics $(\mu_\Phi(B), \mathrm{var}_\Phi(B))$ provide:

- An estimation of target activity in B;
- An associated uncertainty.

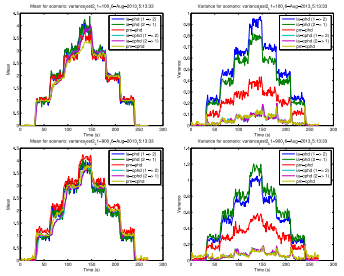
Research axis: exploit $(\mu_\Phi(B), \mathrm{var}_\Phi(B))$ for sensor-level management decision (→ WP2).

Regional information statistics:

- Retrieved from functional representation of point processes;
- Similar to moments for random variables;
- 1st order: mean target number μ_Φ;
- 2nd order: variance in target number var_Φ.



Multi-sensor fusion: comparative study



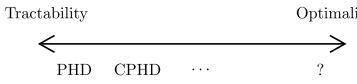
Goal: assess multi-sensor multi-object Bayesian filters

Assessment tool: regional statistics $(\mu_\Phi, \mathrm{var}_\Phi)$

Research axis: propose a reference filter for future performance assessment

Performance evaluation: reference filter

The multi-target Bayes filter is optimal, but intractable in the general case. What if the targets are assumed independent?



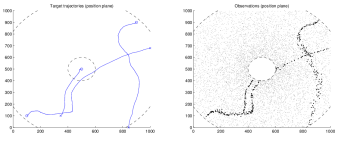
Research axis:

1. Design and implement a reference filter for independent targets;
2. Produce and exploit its regional mean and variance to assess the available filters ("CRLB for multi-object filters").

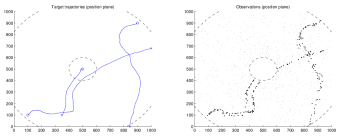
Ongoing development: the *Independent Stochastic Process* (ISP) filter

- Design completed (→ collaboration with J. Houssineau), implementation ongoing;
- Individual tracks are identified by an observation path (i.e. an history of measurements);
- Regional statistics are easily extracted from the filter output;
- Computationally intensive, room for efficient implementation (→ WP6).

Application: modelling of Doppler radar



(a) SNR = 9dB, $P_{\mathrm{fa}} = 10^{-3}$, $P_{\mathrm{d}} = 0.65$



(b) SNR = 9dB, $P_{\mathrm{fa}} = 10^{-4}$, $P_{\mathrm{d}} = 0.43$

Modelling of Doppler radar:

- Parametrisable by physical characteristics (pulse, bandwidth, etc.);
- Stochastic description (SNR, P_{fa}, P_{d}) of local sensor behaviour in an elementary cell → well adapted to ISP filter;
- Two degrees of freedom among SNR, P_{fa}, and P_{d}.

Research axis: integrate stochastic description of sonar systems (→ WP3).

Conclusion:
Recent developments in multi-object Bayesian estimation techniques allow:
- The design of multi-object filters propagating information on target population as well as individual targets;
- The construction and exploitation of higher-order regional statistics estimating the level of target activity anywhere in the surveillance scene.

Future Work:
1. Design of an assessment tool for multi-object solutions based on the ISP filter;
2. Exploitation of regional statistics for sensor-level control policies;
3. Integration of multi-sensor management to multi-object Bayesian estimation framework.

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