[O02] Generic Distributed Target Tracking Algorithms in Sensor Networks

Theme: Distributed Signal Processing

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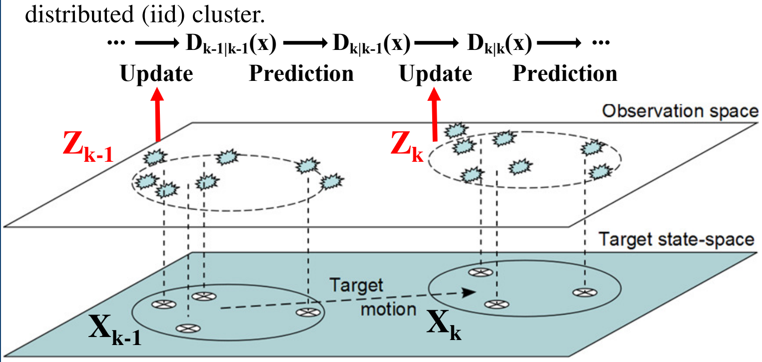
STATUS QUO

- We are investigating detection, localisation and tracking in a ***distributed multi-sensor multi-target tracking*** (***DMMT***) scenario.
- We aim to develop novel strategies for DMMT to enable distributed multi-sensor exploitation under an unknown communication topology.
- Existing approaches include using statistical model selection, e.g., Multiple-Hypothesis Tracking (MHT), based local trackers and fusing associated tracks after a track-to-track assignment stage:
  - Combinatorial increase in the number of hypothesis with measurements: Inherently requires approximation strategies which might result, e.g., deletion of valid target tracks.
  - Track-to-track association errors combined with inaccurate local tracks inhibit robust operation and degrade tracking accuracy.
- We use Bayesian multi-target trackers on sensors which provide i) scalability with the number of measurements, ii) Bayesian summary of the past measurements preventing errors such as deletion of valid target tracks, and, iii) a Bayesian update of the target states.
- We use a suboptimal fusion method which i) improves localisation accuracy, ii) does not require track-to-track associations, and, iii) performs under unknown dependencies enabling a distributed operation.

TECHNICAL WORK

- Local platforms use Bayesian multi-target trackers derived using Random Finite Set (RFS) models and Finite Set Statistics (FISST) tools which avoid explicit target associations.

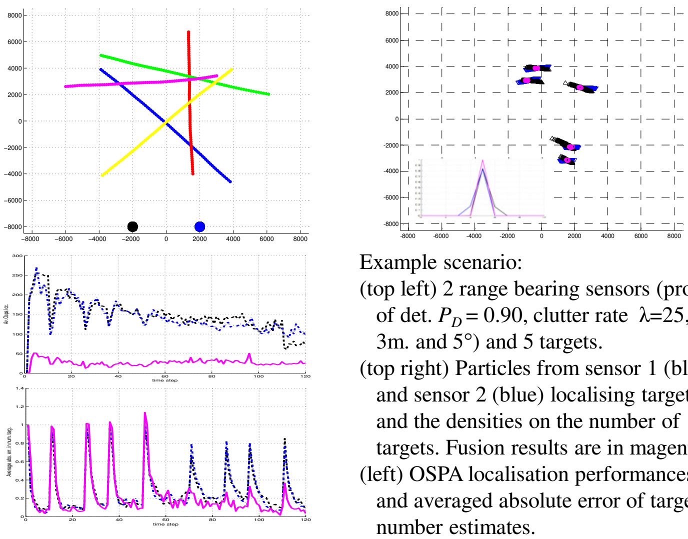
Ex: PHD/CPHD filters modeling the multi-object scene with RFS distributions of type multi-object Poisson/independent identically distributed (iid) cluster.



- Robust Fusion of PHD/CPHD filters using Exponential Mixture Densities (***EMD***) of the posterior distributions. EMDs approximate the joint posterior $f(X \mid Z_0^{1:k} \cup Z_1^{1:k})$ by

$$f_w(X \mid Z_0^{1:k}, Z_1^{1:k}) = \frac{f_0^{(1-w)}(X \mid Z_0^{1:k}) f_1^{w}(X \mid Z_1^{1:k})}{\int f_0^{(1-w)}(X' \mid Z_0^{1:k}) f_1^{w}(X' \mid Z_1^{1:k}) dX'}$$

- Here, $\omega \in [0,1]$ and an optimal value can be selected through information measures on f_ω [3].
- In order to realise this approach:
  - We have derived explicit formulae for EMDs of relevant RFS distribution families [1],
  - We have developed computational strategies using Monte Carlo (***MC***) Methods [2],
  - We have investigated selection of ω using different information measures [3].



Example scenario:
(top left) 2 range bearing sensors (prob. of det. $P_D = 0.90$, clutter rate λ=25, std. 3m. and 5°) and 5 targets.
(top right) Particles from sensor 1 (black) and sensor 2 (blue) localising targets and the densities on the number of targets. Fusion results are in magenta.
(left) OSPA localisation performances and averaged absolute error of target number estimates.

SUMMARY

- This work is motivated by the importance of Distributed Multi-Target Multi-Source Detection (***DMMD***) in the concept of Network Centric Operations (***NCO***). Current approaches to DMMD suffer from computational complexity and related robustness and accuracy issues.
- We use a Bayesian multi-object filtering approach on sensor platforms (e.g., PHD/CPHD filters) which provides a scalable and rigorous alternative together with EMDs for suboptimal yet robust fusion of posteriors.
- The target localisation accuracy is successfully improved in a distributed setting. The cardinality distribution is less prone to the effects of clutter.

REFERENCES

[1] D. Clark, S. Julier, R. Mahler, B. Ristić, "Robust Multi-Object Sensor Fusion with Unknown Correlations," SSPD 2010. [2] M. Üney, S. Julier, D. Clark, B. Ristić, "Monte Carlo Realisation of A Distributed Multi-Object Fusion Algorithm," SSPD 2010. [3] M. Üney, D. Clark, S. Julier, "Information Measures in Distributed Multitarget Tracking," FUSION 2011. [4] M. Üney, D. Clark, S. Julier, "Multi-object Exponential Mixture Density Fusion in Distributed Multitarget Tracking", to be submitted.

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MINISTRY OF DEFENCE

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