WP1.2 Scalable dynamic and distributed inference

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Context and objectives

❑Scalable solutions to approximate inference in distributed and modular sensor networks: signal detection/object tracking problems

❑Scalability issue of existing filters – main concern

❑Two families of Bayesian inference

- **Data-driven filters**: Dynamic state space model (DSM) is unknown, training data set is provided
  – Propose the Gaussian process-message passing (GP-MP) based algorithm
- **Model-driven filters**: DSM is given explicitly
  – Propose the adaptive kernel Kalman filter (AKKF)
  – Joint Spatio-Temporal Bias Estimation and Tracking

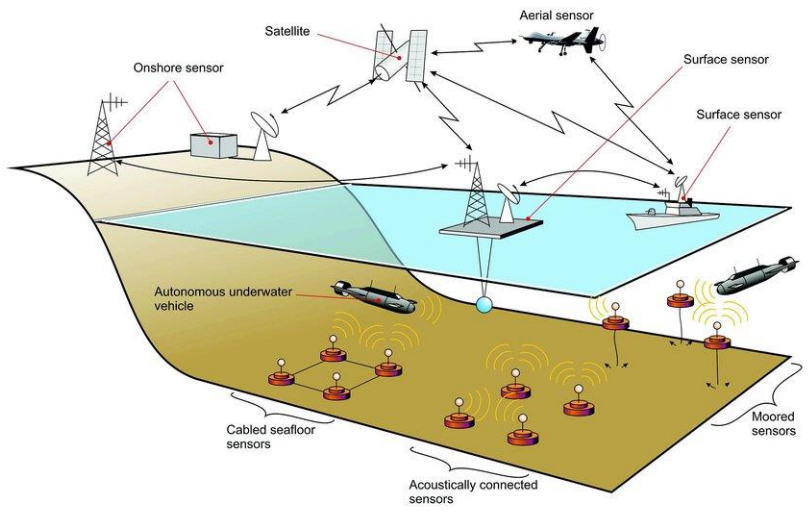


Fig. An example of a distributed sensor network

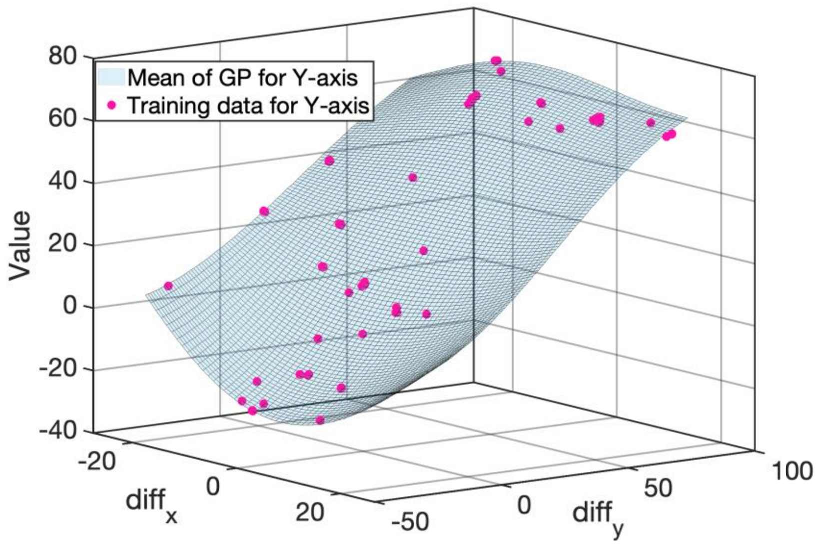


Fig. An example of two-dimensional GPR

Data-driven Bayesian inference – GP-MP based multi-target tracking

- ❑ Design the Gaussian process – message passing (GP-MP) based algorithm for object tracking
- ❑ Advantages
  - Data-driven DSM
  - No need for multiple models
  - Scalable multi-target tracking

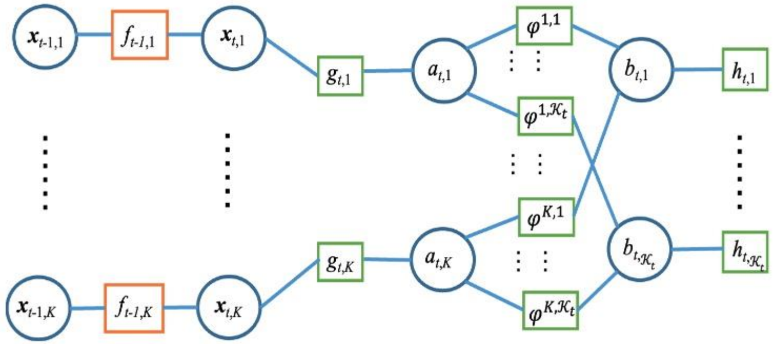


Fig. Factor graphs for single-sensor MTT

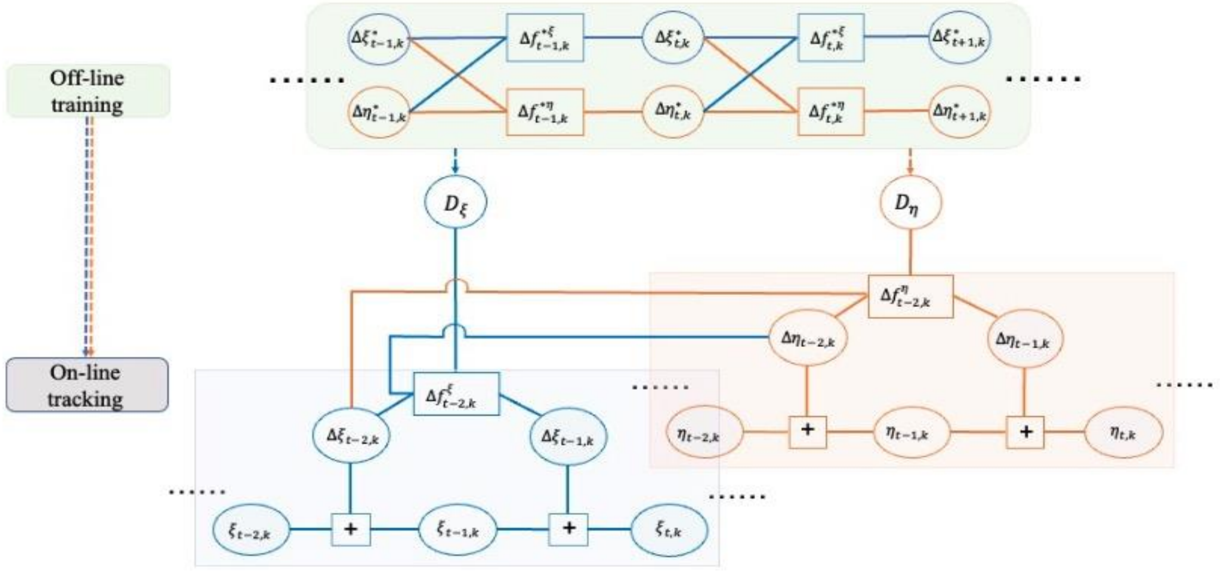


Fig. Factor graph of the proposed joint GP algorithm for state prediction

- M. W. Sun, M. E. Davies, I. Proudler, J.R. Hopgood, "A Gaussian Process based Method for Multiple Model Tracking," 2020 Sensor Signal Processing for Defence Conference (SSPD2020), published.
- M. W. Sun, M. E. Davies, I. Proudler, J.R. Hopgood, "Maneuvering Multi-target Tracking Based on Gaussian Process Regression," IEEE Transactions on Aerospace and Electronic, submitted

Model-driven Bayesian inference – New filter design

❑Kernel mean embedding (KME)

❑Propose the Adaptive kernel Kalman filter (AKKF)

❑Advantages

- Avoid particle filter resampling step
- Good scalability
- Give a new insight on model-based and data-based filters
- Potential for improving the loopy belief propagation

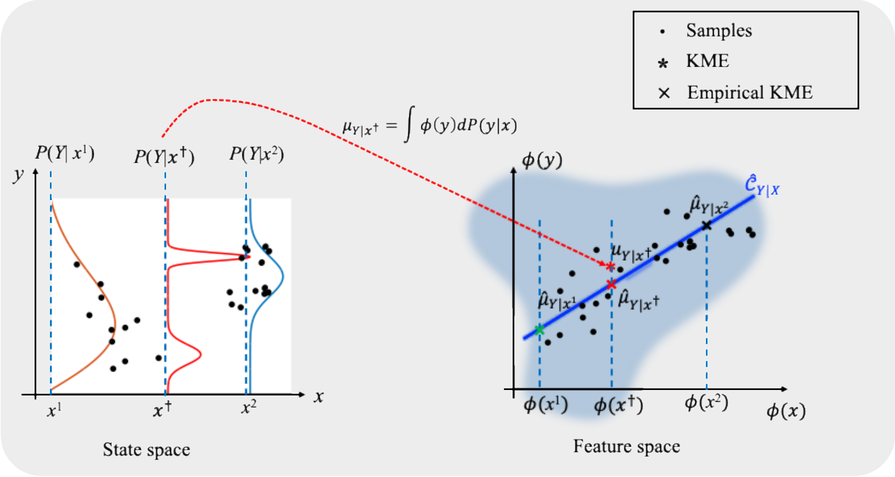


Fig. KME of a conditional distribution

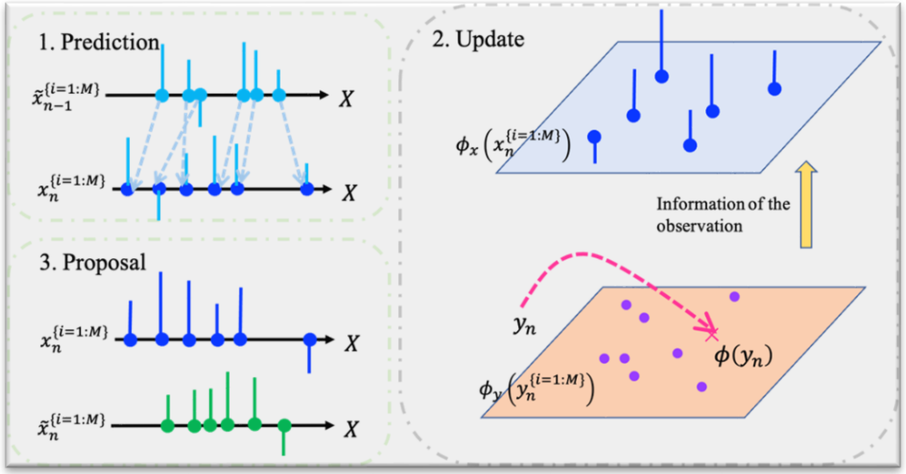
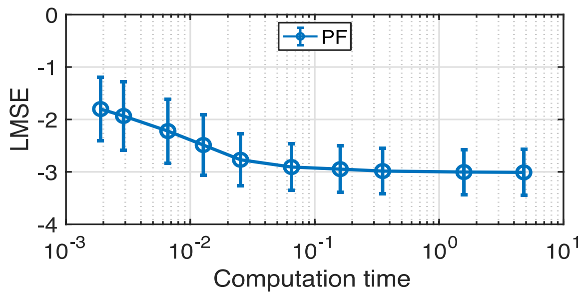


Fig. Realisation of AKKF

- M. W. Sun, M. E. Davies, I. Proudler, J.R. Hopgood, "Adaptive Kernel Kalman Filter," 2021 Sensor Signal Processing for Defence Conference (SSPD2021), published
- M. W. Sun, M. E. Davies, I. Proudler, J.R. Hopgood, "Adaptive Kernel Kalman Filter Multi-Sensor Fusion," 2021 24th International Conference on Information Fusion (FUSION), published.
- M. W. Sun, M. E. Davies, I. Proudler, J.R. Hopgood, "Adaptive Kernel Kalman Filter," IEEE Transactions on Signal processing, Submitted.

Model-driven Bayesian inference – Applications of the AKKF

- Single target tracking



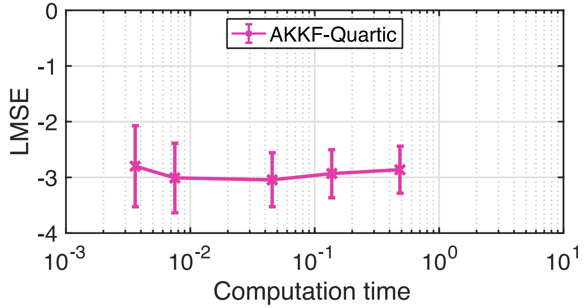
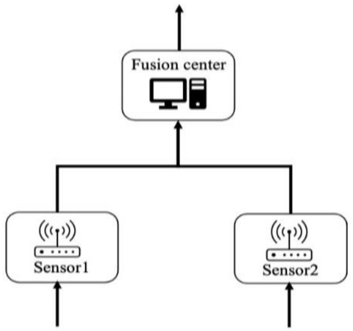
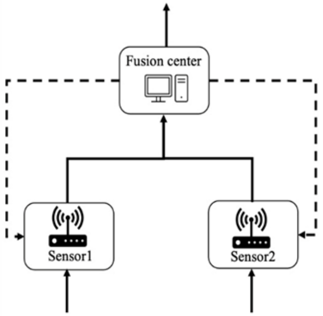


Fig. Comparisons of computation time and tracking performance of the PF and the AKKF

- Multi-sensor fusion



(a)
Centralized fusion



(b)
Semi-Decentralized fusion

Fig. Different fusion schemes

- Multi-target tracking

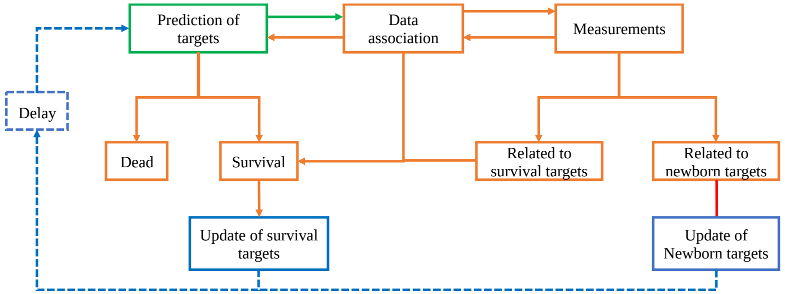
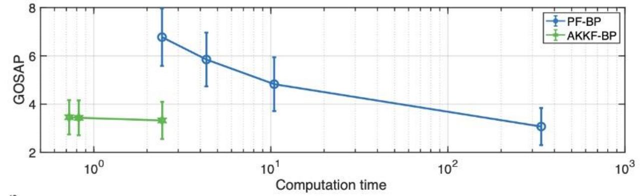


Fig. Flow diagram of the proposed AKKF based BP algorithm



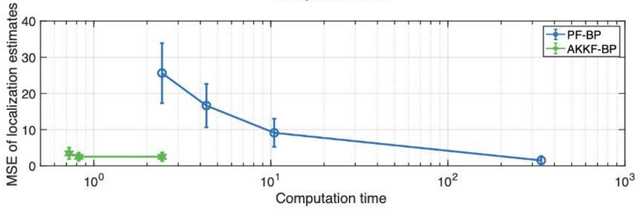


Fig. GOSAP and localization estimation error of the detected targets comparisons

- M. W. Sun, M. E. Davies, I. Proudler, J.R. Hopgood, "Adaptive Kernel Kalman Filter based Belief Propagation Algorithm for Maneuvering Multi-target Tracking," IEEE Transactions on Aerospace and Electronic Letter, in preparation.

Model-driven Bayesian inference
– Joint Spatio-Temporal Bias Estimation and Tracking

- **Problem**: Sensor calibration for reliable object tracking without a global frame of reference
- **Proposed solutions:** Grid-based search method with likelihood function to test the bias state space.
- **Advantages**
  - Tracking performance improvement
  - Registration errors are corrected
  - Increase in accuracy over object tracking with only a single sensor

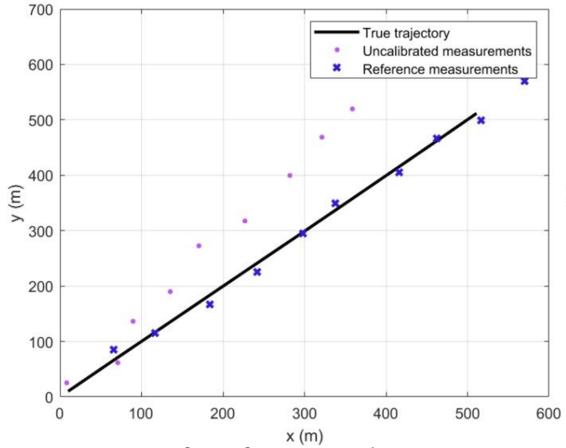


Fig. Before fusion and correction

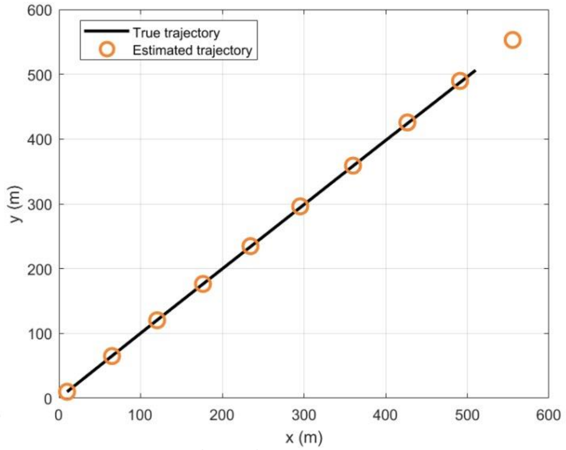


Fig. After fusion and correction

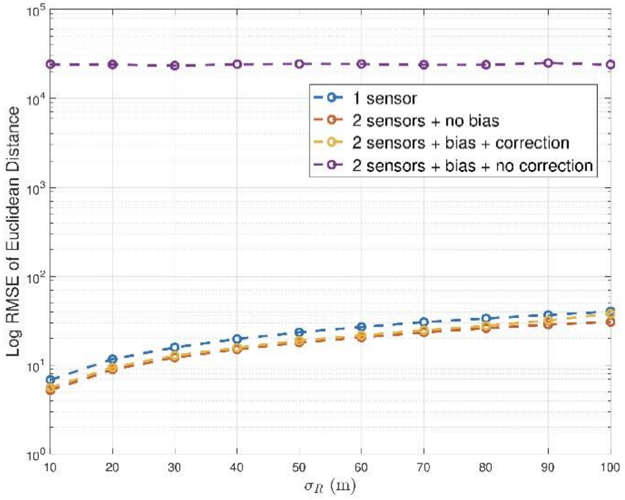


Fig. Tracking performance vs σ_R

• S. Macdonald and J. R. Hopgood, "Joint Spatio-Temporal Bias Estimation and Tracking for GNSS-Denied Sensor Networks," 2021 Sensor Signal Processing for Defence Conference (SSPD), 2021