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Optimal federated fusion of multiple maneuvering targets based on multi-Bernoulli filters

Key words: Uncertain maneuvering targets; Joint multi-Gaussian mixture multi-Bernoulli (JMGM-MB) filter; Hierarchical structure; Optimal fusion; Correlations

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Motivation

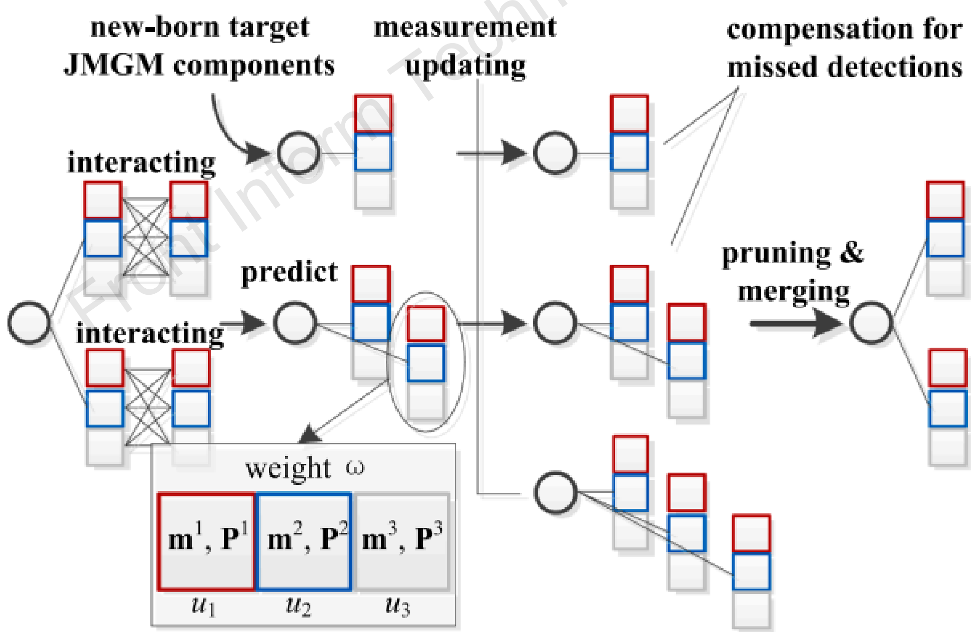
1. The MM-MB filter is a typical benchmark in constructing decentralized fusion of a time-varying number of maneuvering targets. However, the MM-MB filter is not theoretically optimal as it is actually propagated in the GPB-1 manner.
2. The existing decentralized fusion of multiple tracking filters suffers from ineluctable correlations arising from common process noise and feedback, resulting in the suboptimality of the decentralized fusion. Decorrelation is always challenging for decentralized fusion tracking tasks.
3. The major obstacle of applying the single-target decorrelation method is the lack of prior estimates in the existing decentralized fusion structure.

Main idea

1. The more advanced JMGM-MB filter is adopted to track a time-varying number of maneuvering targets, which propagates the distribution of each latent target in the interactive multi-model (IMM) manner.
2. The celebrated covariance upper-bounding technique is employed to eliminate correlations among multiple tracking filters.
3. A master filter is introduced to automatically provide prior estimates required by the covariance upper-bounding technique.

Method

1. The JMGM-MB filter behaves better in tracking multiple maneuvering targets. Each single-target state estimate is expressed as a set of model-related Gaussian functions with model probabilities, which are propagated in the IMM manner.



Method (Cont'd)

2. The celebrated covariance upper-bounding technique is leveraged to realize decorrelation. The optimal estimate fusion is derived via reconstructing the Bayesian measurement fusion, eliminating the correlations by expanding prior covariances.

$$\boldsymbol{P}_m^{-1}(\boldsymbol{Z})\boldsymbol{m}_m(\boldsymbol{Z})=\beta(0)\boldsymbol{P}_m^{-1}\boldsymbol{m}_m+\sum_{s=1}^{S}\beta(s)\boldsymbol{P}_m^{-1}\boldsymbol{m}_m+\left(\boldsymbol{H}^{(s)}\right)^{\mathrm{T}}\left(\boldsymbol{R}^{(s)}\right)^{-1}\boldsymbol{z}^{(s)}, \tag{9}$$

$$\boldsymbol{P}_m^{-1}(\boldsymbol{Z})=\beta(0)\boldsymbol{P}_m^{-1}+\sum_{s=1}^{S}\beta(s)\boldsymbol{P}_m^{-1}+\left(\boldsymbol{H}^{(s)}\right)^{\mathrm{T}}\left(\boldsymbol{R}^{(s)}\right)^{-1}\boldsymbol{H}^{(s)}, \tag{10}$$

$$u_m(\boldsymbol{Z})=\frac{u_m\cdot\prod_{s=1}^{S}\left(g_m\left(\boldsymbol{z}^{(s)}\right)u_m\right)/u_m^S}{\sum_{m=1}^{N}u_m\cdot\prod_{s=1}^{S}\left(g_m\left(\boldsymbol{z}^{(s)}\right)u_m\right)/u_m^S}, \tag{11}$$

Method (Cont'd)

3. A hierarchical structure is designed for decentralized decorrelation tracking, yielding the proposed federated fusion. Since the covariance upper-bounding technique requires prior estimates, the fusion node is equipped with a master filter.

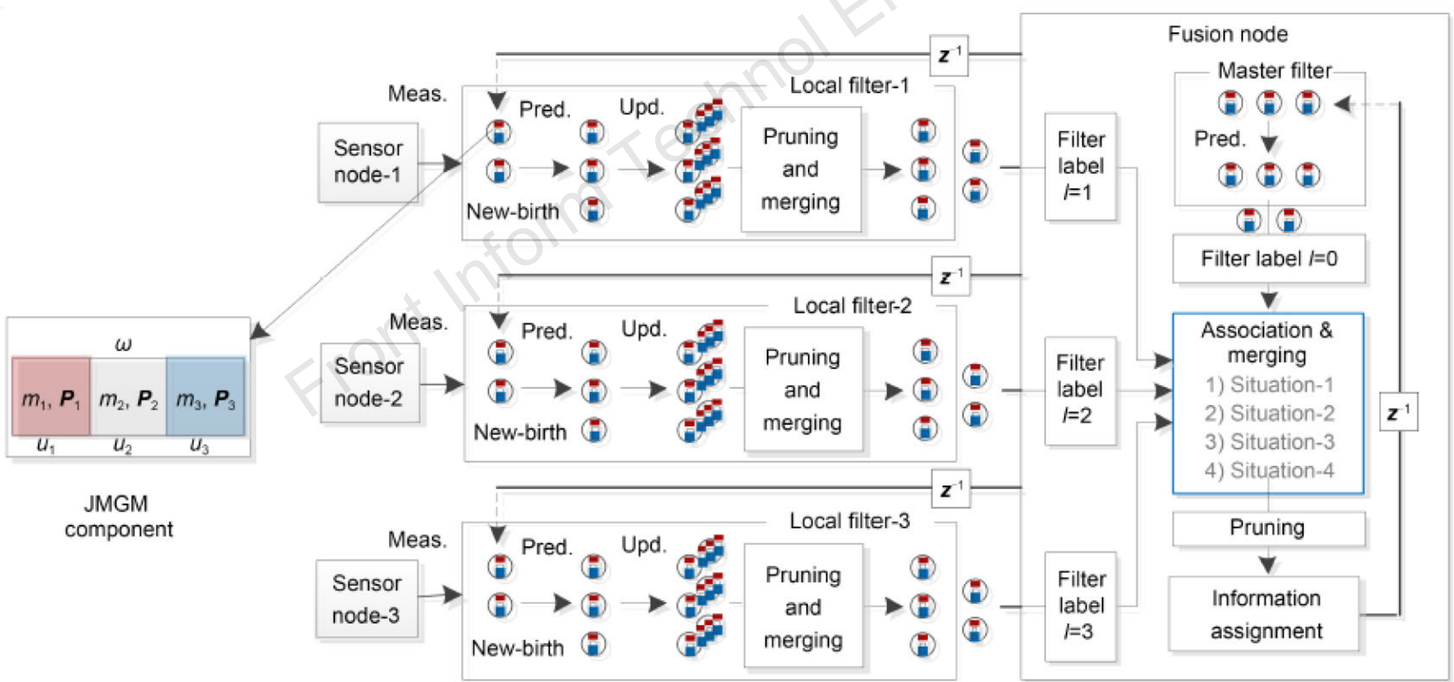


Fig. 1 Structure of the proposed federated fusion of JMGM-MB filters (assuming the number of models N=3). Meas.: measurement; Pred.: prediction; Upd.: update

Major results

The best performance in finding target maneuvers and the accurate association in decentralized fusion

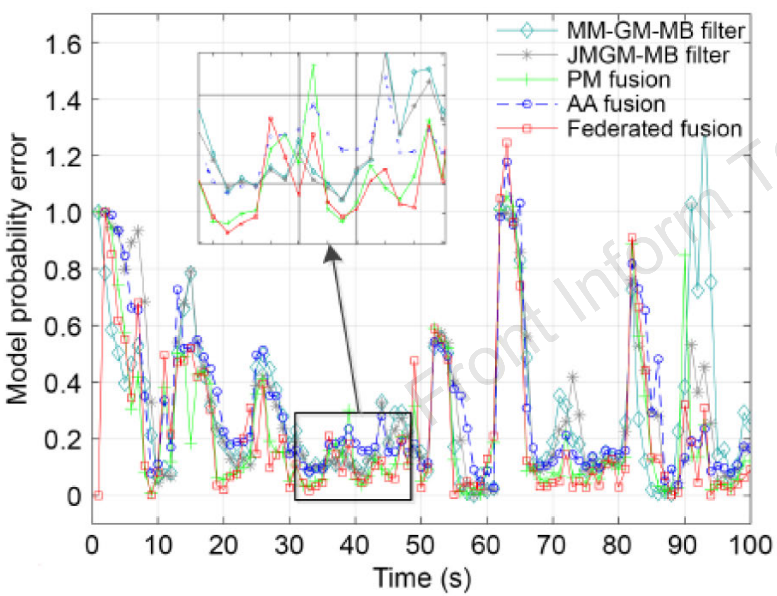


Fig. 3 Multi-target model probability error curves of different algorithms

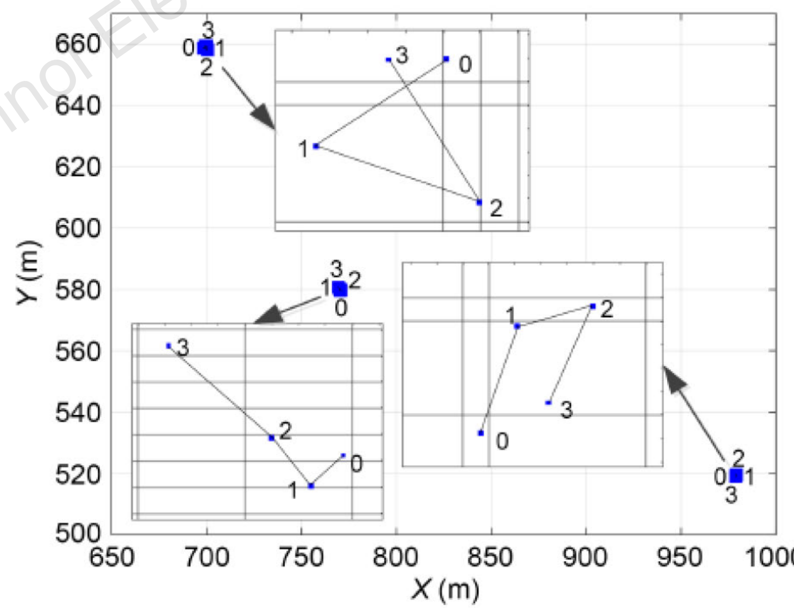


Fig. 5 Estimates of T-BCs associated at 40 s

Major results (Cont'd)

The proposed fusion algorithm exhibits the lowest OSPA error curve

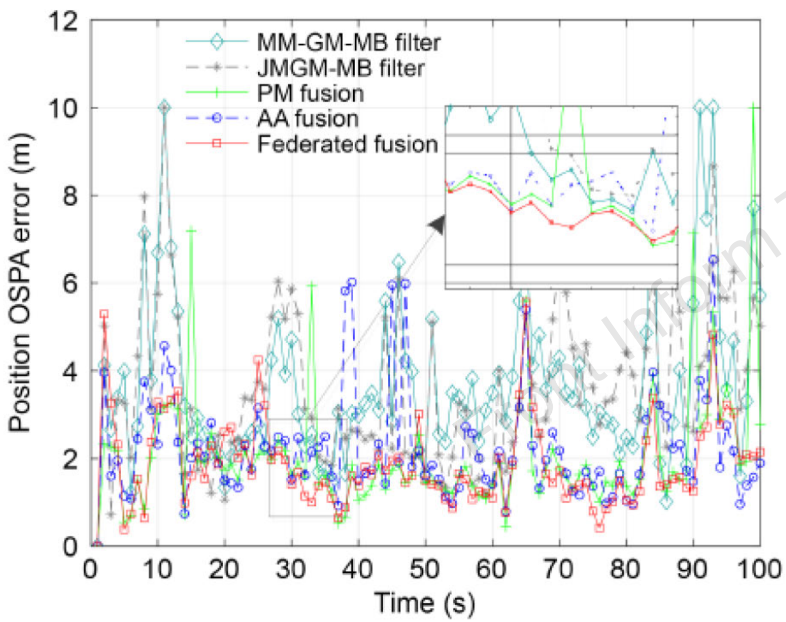


Fig. 7 OSPA error curves of different algorithms

Table 2 Statistics of different algorithms

Algorithm	OSPA error (m)		
	Mean	Std	Max
MM-GM-MB	4.0270	1.8913	9.9564
JMGM-MB	3.4459	1.7557	9.0112
PM fusion	2.1469	1.1764	7.3776
AA fusion	2.2615	1.2589	8.0627
Federated fusion	2.0058	0.9422	6.0762

Major results (Cont'd)

Satisfactory tolerance to missed detections in linear and nonlinear scenarios

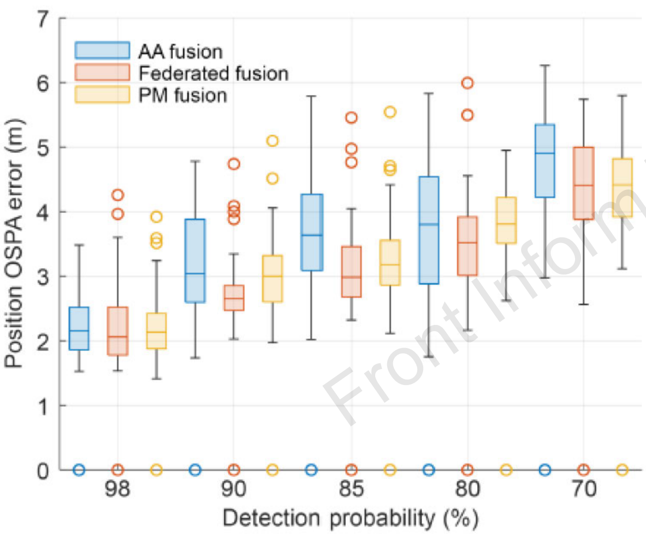


Fig. 13 Box plot in the linear scenario (References to color refer to the online version of this figure)

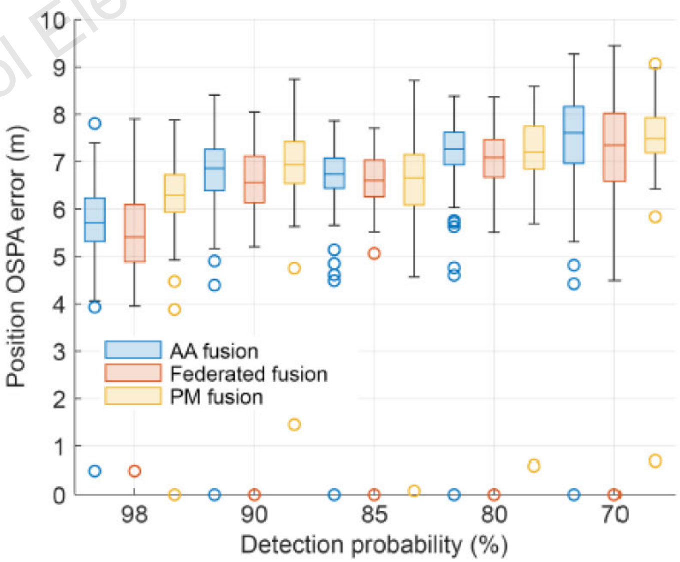


Fig. 14 Box plot in the heterogeneous scenario (References to color refer to the online version of this figure)

Conclusions

1. The centralized and decentralized fusion approaches of the advanced JMGM-MB filters are successfully achieved.

2. A multi-target federated fusion with decorrelation ability is proposed via expanding prior covariances involved, whose optimality is guaranteed by the covariance upper-bounding technique.

3. A hierarchical fusion structure is designed, where a master filter that performs prediction only is leveraged to provide indispensable prior JMGM components.