Parameter identification of a distributed multisensor filtering system

Innokentiy V. Semushin[1] ; Yulia V. Tsyganova[1,*] ; Andrey V. Tsyganov [2]
[1]Ulyanovsk State University, [2]Ulyanovsk State Pedagogical University named after I.N. Ulyanov

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Abstract

The paper addresses the problem of parameter identification of a distributed multisensor filtering system. To solve the problem, a new hybrid parameter identification algorithm based on the auxiliary performance index (API) is proposed. For the first time, it is shown how the API gradient can be calculated in a decentralized manner. The algorithm is implemented and tested in MATLAB.

Parameter identification method

Let us consider a distributed multisensor system for filtering a useful signal $x(t_k)$ according to measurement data $y_i(t_k)$, available from i=1,2,…,m sensors at discrete time instants $t_k = kT$ (k=1,2,…,N), where T denotes the given measurement rate. Let the mathematical model of this system be described by difference equations [3]:

$$\left.\begin{aligned} x(t_k) &= dx(t_{k-1}) + A\sqrt{1-d^2}\,w(t_k) \\ y_i(t_k) &= x(t_k) + v_i(t_k), \quad i = 1,2,\dots,m \end{aligned}\right\} \qquad (1)$$

where $w(t_k)$ и $v_i(t_k)$ are mutually independent discrete white noises with zero mean and covariances $Q = 1$ and $R_i = B_i^2$. Let $\theta = (d, A^2, B_1^2, \dots, B_m^2)^T$ be the parameter vector of model (1). If θ is known, then filtering of the useful signal $x(t_k)$given the multisensor data $y_i(t_k)$ can be performed with the information Kalman filter.

We consider system (1) with parameter uncertainty, i.e., we suppose that the value of parameter θ is unknown. The problem of parameter identification is to calculate the estimates of the unknown parameter θ according to the data of multisensors $y_i(t_k)$.

To solve, we use the API method [4], which allows us to obtain unbiased estimates of the parameter vector θ from the observed input and output data. Let us construct an identification criterion in the form of API. Let $D(\theta)$ be the domain of parameter θ. Parameter identification algorithm is built by implementing the procedure for numerical minimization of the API criterion, i.e. an estimate $\hat{\theta}^*$ is calculated according to

$$\hat{\theta}^* = \underset{\hat{\theta}\in D(\theta)}{\operatorname{argmin}} J_{API}(\hat{\theta}).$$

The paper proposes a new hybrid algorithm for parameter θ identification.

Main result

Statement. The API values and its gradient

$$\nabla_\theta J_{API}(\hat{\theta}) = \left[\frac{\partial J_{API}(\hat{\theta})}{\partial \theta_1}, \quad \dots, \quad \frac{\partial J_{API}(\hat{\theta})}{\partial \theta_p}\right]^T$$

in the parameter identification algorithm are calculated as

$$J_{API}(\hat{\theta}) = \frac{1}{N}\sum_{k=1}^{N}\left[\varepsilon_k^-(\hat{\theta})\right]^2 \text{ and } \frac{\partial J_{API}(\hat{\theta})}{\partial \theta_j} = \left.\frac{\partial J_{API}(\theta)}{\partial \theta_j}\right|_{\theta=\hat{\theta}}$$

$$= \frac{2}{N}\sum_{k=1}^{N}\varepsilon_k^-(\hat{\theta})\left.\frac{\partial \varepsilon_k^-(\theta)}{\partial \theta_j}\right|_{\theta=\hat{\theta}}$$

where $p = m + 2$, $\hat{\theta}$ is an estimate of θ, $\varepsilon_k^-(\hat{\theta}) = \frac{1}{m}\sum_{i=1}^{m} y_i(t_k) - s_k^-(\hat{\theta})/\lambda_k^-(\hat{\theta})$, values of $s_k^-(\hat{\theta})$ и $\lambda_k^-(\hat{\theta})$ are obtained in distributed information Kalman filtering framework; see [3, sect. 4].

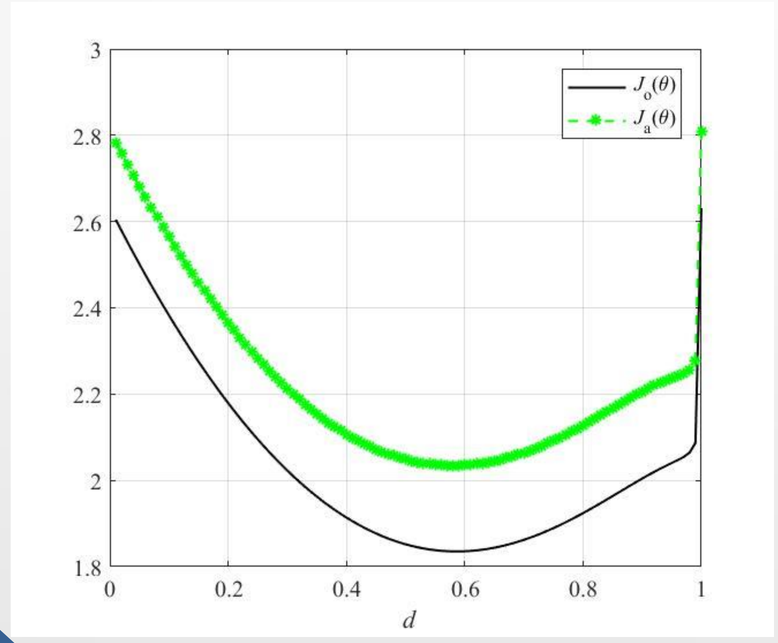

Figure 1: Values of OPI and API calculated based on N = 500 measurement data from 4 sensors vs parameter d of the identification algorithm

Conclusions

We have constructed a new hybrid algorithm for parameter identification of a distributed multisensor filtering system based on applying the API method. The hybrid nature of the algorithm means the combination of two steps:

1) calculation of the initial approximation by the meta-heuristic algorithm and
2) correction of the found estimate by the gradient algorithm.

For the first time, it is shown how to calculate the gradient of the API criterion in a distributed multisensor system. The algorithm is implemented and tested in MATLAB.

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Contacts

*Yulia V. Tsyganova
Email: tsyganovajv@gmail.com
Ulyanovsk State University
Site: www.ulsu.ru