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MULTI-MODEL METHODS AND PARAMETERS ESTIMATION APPROACHES ON NON-LINEAR DYNAMIC SYSTEM IDENTIFICATION

Abstract. In this article the new approach of the extremum estimation in the non-linear dynamic system identification problem are proposed. Major drawback of the previous approach is fixed. A series on simulations, that justifies new method was held.

Keywords: non-linear dynamic system identification, multi-model identification methods, simulation, extemum estimation.

Introduction

Parametric identification of the complex non-linear dynamic systems is not only complex, but also a time-consuming task. One of the reasonable approach to significantly decrease identification time is to use the ensemble of the models and searching agents in conjunction with the adaptive-searching methods [1,2]. Obviously, using such methods implies existence of the proper identification criterion. On the other hand, every tactics for the agents ensemble requires existence not only criterion, but a algorithm for the searching movement. Most of applied algorithms, in turn, requires method to determine the place of the local extremum point (if any).

In the previous papers some approaches to this task was considered. Simulation results shown applicability of these approaches, but the further investigations shows some drawbacks. In this paper the phenomena and methods to workaround these drawbacks will be considered.

Task definition

Lets assume, that we have object "O" and the ensemble of the models "M_i", $i \in [0, n-1]$. For every other definitions we will designate by the "*o*" index the values, which belongs to object, and index "*mi*" – to model number *i*. In this paper In this paper only 3 adjacent models will be simulated, and this models will receive indexes "l", "c" and "r". As it was done in previous papers, we will use simple, but non-linear model of the criterion and parameter dependency:

$$q_{mi}\left(p_o, p_{mi}\right) = a_l\left(p_o - p_{mi}\right) + a_a\left|p_o - p_{mi}\right|, \qquad (1)$$

where p – parameter, q – criterion, a_l – linear sensitivity coefficient, a_a – non-linearity (absolute value) coefficient. The distance in the parameter space between neighboring models will be equal: $p_r = p_c + A$, $p_r = p_c + A$. As an example of real non-linear dynamic object, a well-known Lorenz system [3] will be used.

Function of quality F represented by this way:

$$F(q_{mi}) = \exp\left(-\frac{q_{mi}^2}{q_\gamma^2}\right), \qquad (2)$$

where q_γ – sensitivity scale. It is possible to use other similar representation of this function, but in this case it does not make significant sense.

A series of identification process simulations with different values of identification system parameters was held, and the RMS of the identification errors was measured. The value of $\overline{e}_{ge}$ describes identification error, if the value of the estimated parameter if given as:

$$p_{ge} = \frac{F_l p_l + F_c p_c + F_r p_r}{F_l + F_c + F_r}. \qquad (3)$$

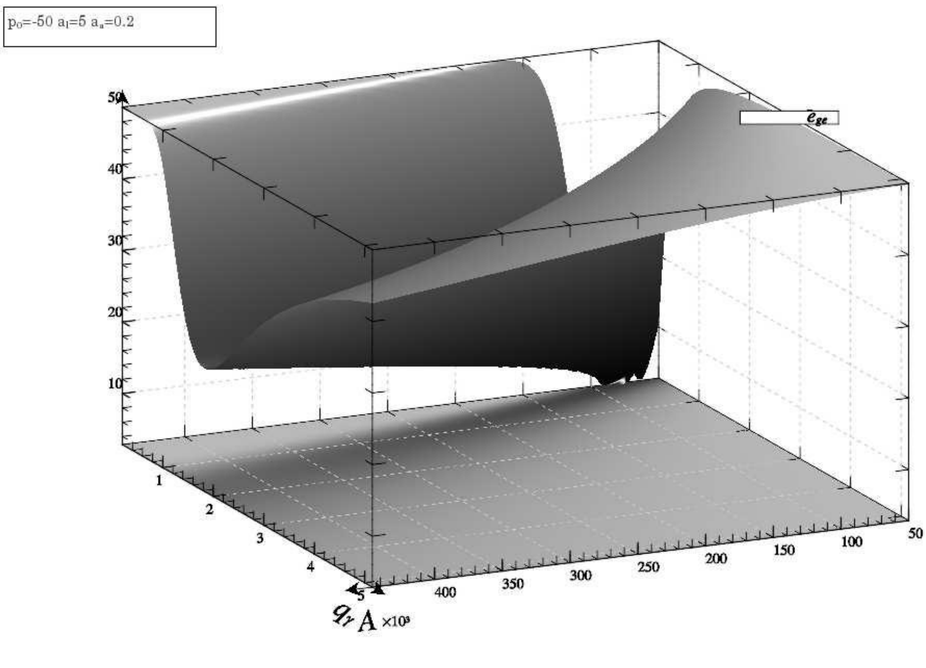

Fig. 1 – Dependence $\overline{e}_{ge}(q_\gamma, A)$ for the model (1)

In the fig. 1 the dependence $\overline{e}_{ge}(q_\gamma, A)$ is shown. The minimal value of the parameter "A" was chosen as $A = |p_o|$, to ensure, that real extremum is placed inside models. We can see, that successful identification is possible only inside quite narrow "valley". This drawback prevents from effective usage of the extremum estimation in the form of (3), as it requires too many information about system under identification, but such information will be available only after identification itself. Moreover, the more non-linear properties system demonstrates, the shorter will be the "valley".

The second approach to estimate the extremum position is to approximate function $F(p)$ by parabola $F(p) \approx a_2(p - p_c)^2 + a_1(p - p_c) + a_0$. It was considered only the case, where $a_2 < 0$ and estimated value p_{ee} is limited to half-with of A. The first condition is quite obvious, and the second was imposed due to some details in the implementation of the some searching algorithms, where important condition was non equal values of adjacent p_{ee_i}.

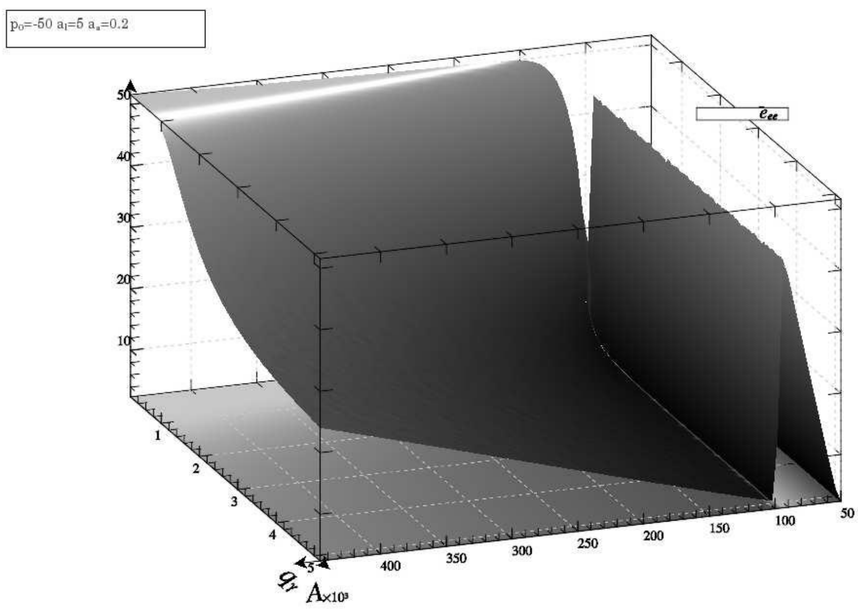

Fig. 2 – Dependence $\overline{e}_{ee}(q_\gamma, A)$ for the model (1)

In the fig. 2 the resulting dependence $\overline{e}_{ee}(q_\gamma, A)$ is shown, where $\overline{e}_{ee}$ corresponds to p_{ee}. We can easily notice, that unlike fig. 1 correct estimation occurs in much wider area. Moreover, this picture remains near the same for mush large values of q_γ, that corresponds to minimal sensitivity. But essential drawback is striking in the right part of the plot. Surprisingly high values of $\overline{e}_{ee}$ are observed near line $A = 2|p_o|$. This fact disturbs identification process in the area, situated near real exremum.

The similar results was achieved while parametric identification of the Lorenz chaotic system (fig. 3).

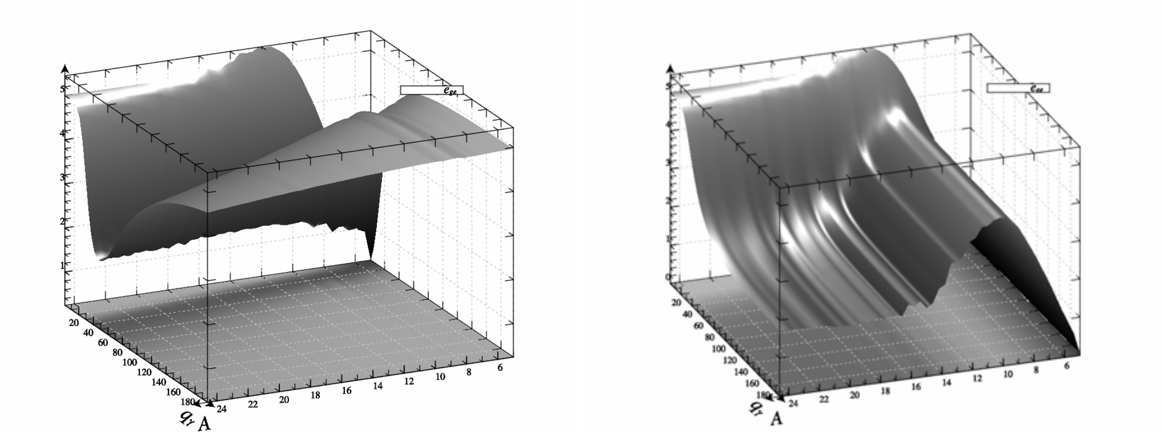

Fig. 3 – Dependencies $\overline{e}_{ge}(q_\gamma, A)$ and $\overline{e}_{ee}(q_\gamma, A)$ for the Lorenz system

So, to achieve better results for the identification problem, its vital to provide better method to local extremum approximation.

Analysis and conclusion

According to existent properties of p_{ge} and p_{ee} extremum approximation, the second one was chosen as candidate to improvement. Manual investigation of the values near the problem area shows, that the main reason of such undesirable behavior is artificial parameter limiting to half-width in conjunction with automatic selections of the next best model. It was reasonable in the method with models with fixed parameters, but leads to exception of the large parametric range.

So, to prevent such exception, it may be reasonable to use not half-with range, but all available range between models:

$$p_{ee} \in (p_l, p_r). \tag{4}$$

This approach may lead to problems, if the values of p_{ee} from the neighbor models is used directly my the identification method. On the other hand, such methods appears as not enough effective, so in this case we may neglect this drawback.

Simulation results

To test this proposition, a new series of simulation were held by the means of the program “qontrol”. All parameters was the same, ex-

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cept limiting range to p_{ee}, which was now defined as (4). New RMS error dependencies is show in fig. 4–6.

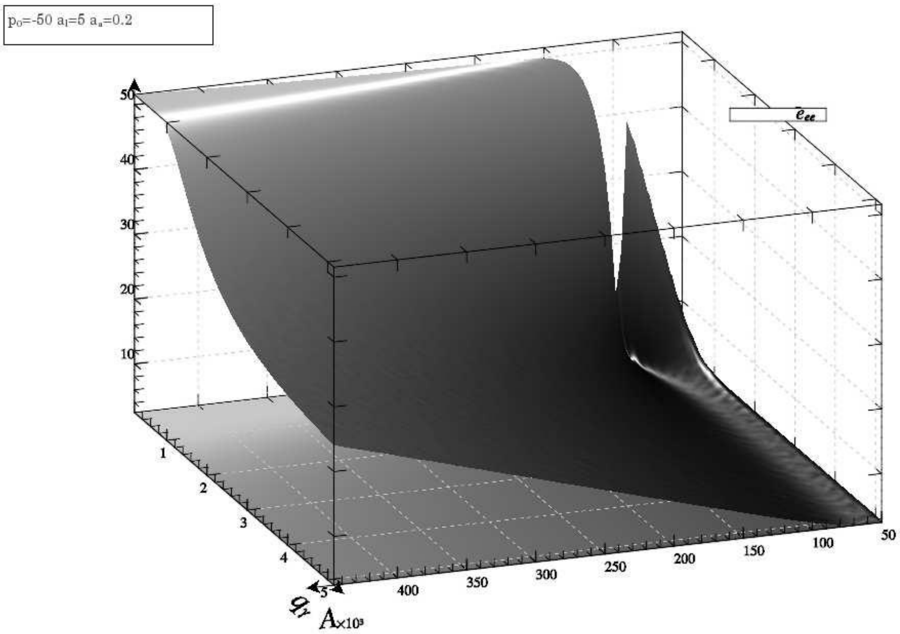

Fig. 4 – New dependence $\overline{e}_{ee}(q_\gamma, A)$ for the model (1)

Fig. 4 demonstrate dramatic enhancement of the $\overline{e}_{ee}(q_\gamma, A)$ dependence in the area $A \in \left[|p_o|, 2|p_o|\right]$. Now it is the area with minimal RMS error. This fact may be used by many identification method to provide better precision and less identification time due to parameter "A" adaptation.

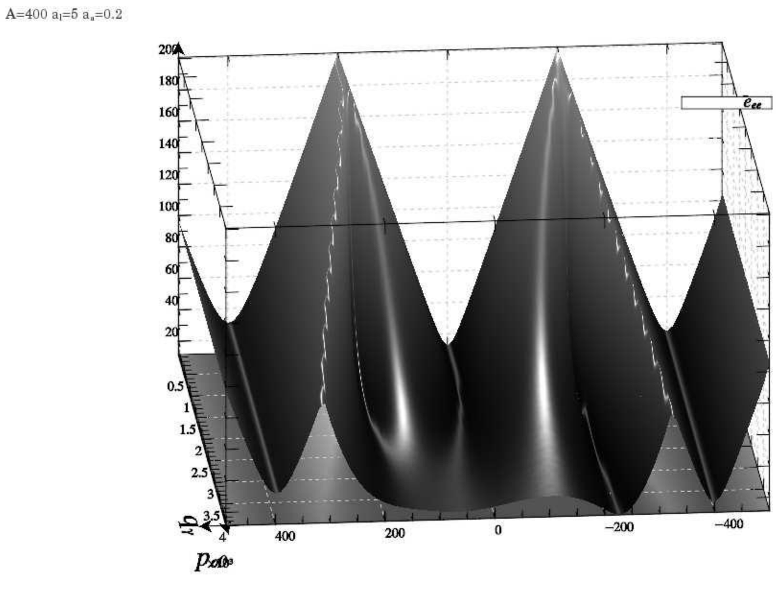

Fig. 5 – New dependence $\overline{e}_{ee}(q_\gamma, p_o)$ for the model (1) at fixed A

The similar result is shown in the fig. 5, where parameter A was fixed, and the values of p_o and q_γ was variable. In the area, where q_γ is not too low, the RMS error is limited.

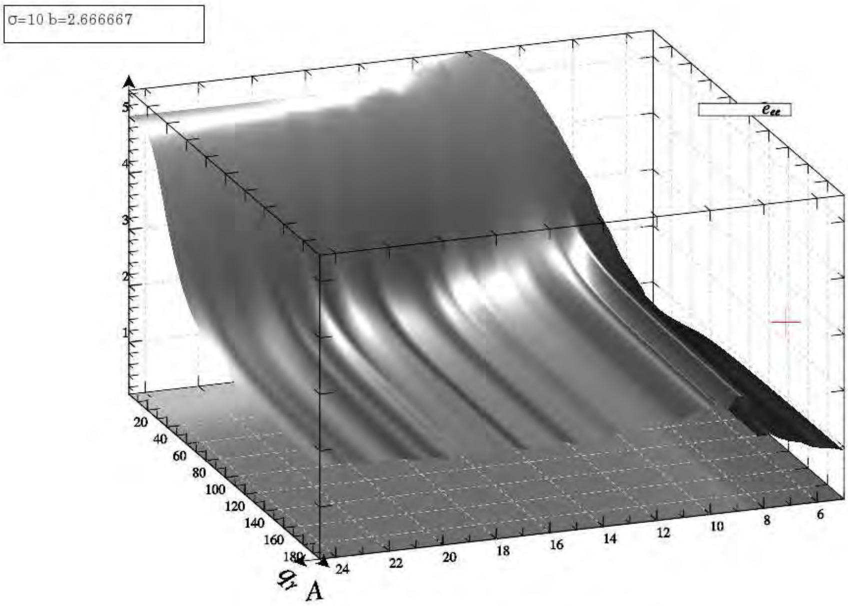

Fig. 6 – New dependence $\overline{e}_{ee}(q_\gamma, A)$ for the Lorenz system

The same changes was observed (fig. 6) in the task of Lorenz system identification.

Conclusions

By the aid of the new approach to limit p_{ee} value (4), it appears, that RMS identification error in the area $A \in \left[|p_o|, 2|p_o| \right]$ became much smaller. This approach gives possibility to essentially improve identification method due to parameters adaptation in the real time.

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