Report

of a member of the dissertation council on the PhD thesis presented by A.O. VEDYAKOVA

Methods of real-time parameter estimation for harmonic signals by delay introduction

submitted for the Candidate of Physical and Mathematical Sciences degree with specialization 05.13.01 – System analysis, information control and processing (physical and mathematical sciences)

Estimation of unknown parameters and unmeasured variables describing dynamics of industrial plants and processes is an important and complex challenge of the theory of control and automation. Despite existence of numerous filtering and estimation approaches, the growing quality requirements and enlargement of the applicability domains lead to a necessity of development of new observation and identification methods. In particular, advanced robustness of the estimation tools in the presence of weak excitation is highly appreciated, under an additional constraint on used computational complexity of the proposed algorithms. Estimation of parameters of harmonic signals (bias, amplitudes, frequencies and phases) is a benchmark example of such a complex estimation problem, which is the main topic considered in the thesis of A.O. Vedyakova. Replacing conventional filtering by delays allows the numeric complexity to be diminished in comparison with other approaches. The investigated in the thesis problems are definitely challenging, and the obtained solutions are original and widely examined during the last decades. Therefore, the thesis is devoted to an actual problem of the theory of control, whose solution is demanded in many applications, which is also demonstrated in the thesis.

The manuscript is clearly written, and well organized. The author explains well the complexity of the studied estimation problem, demonstrating a good understanding of the scientific domain with existing methods and tools.

The manuscript contains three chapters. In Chapter 1 the basic problem of parameter estimation for harmonic signal is introduced and investigated. It is shown that application of delay filters does not destroy the excitation properties of the obtained linear regression model under a mild restriction on the delay value. In Chapter 2, the case with time-varying amplitudes and phases is considered, and it is demonstrated that under some parameterization of the amplitudes, the delay filters allow to derive a linear regression model. A challenging case of exponentially decreasing amplitude is considered (in such a case the persistence of excitation condition is not satisfied), then by using the dynamic regression extension and mixing (DREM) method, it is demonstrated that after additional processing of the regressor, it is possible to recover the needed level of excitation, which is indeed an interesting finding. In Chapter 3 these results are applied to two application scenarios: estimation of angular velocity of rotor for synchronous motor with permanent magnets, and estimation of the main frequencies of sea waves for dynamic navigation of ships.

The presented results are given on a high scientific level, and the numerous publications (10 in total, 3 in leading international journals, and 4 in top international conferences) clearly indicate the good scientific background of A.O. Vedyakova. The presented computations and mathematical proofs are technically sound.

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Nevertheless, I have the following comments:

1. Why there is no analytical analysis of the influence of measurement perturbations on the precision of the obtained estimates and the time of convergence (usually a trade-off has to be found between the time of convergence and robustness)? In the conclusions it is claimed that the proposed method has no trade-off between rate of convergence and robustness. Actually, the thesis does not consider (analytically) the effect of noises, and for the perturbed case only some results of simulations are given.

2. There is an ambiguity with using some symbols. For example, in (1.94) t_0\geq0 should be arbitrary? The same for (1.2)-(1.4)? Between (1.95) and (1.96) it is defined that t_i=t-i\tau, then t_0=t? Next, it is mentioned that \Delta has a period t_0, but before t_0 was an arbitrary initial time instant? Two lines later it is mentioned that t_0>n(\tau+d)? What is the time of convergence in (1.101)?

3. In subsection 1.8.2 it would be interesting also to see the computational complexity of all algorithms used for comparison. Why the time of convergence is much slower for the case of noisy measurements? Why the algorithms are tuned differently in the noisy and noise-free cases?

4. The problem (2.3) under Assumption 3 is reduced to the one considered in Chapter 1 (use the substitution y(t) -> y(t)/A(t)). Under assumptions 3 and 4 there is a simple solution: \omega t = \arcsin(y(t)/A(t))?

5. It seems that in subsection 2.4.3, where a frequency estimation method is presented that avoids using the inverse trigonometric function, the gradient method is conventionally applied to solve a scalar (convex?) equation. Highlight the novelty, please.

6. What is a reason of having spikes in the estimates \hat\omega_\arccos in Fig. 2.16? The variable \hat\theta_3 was also projected to the interval \cos([\underline\omega\tau_1,\overline\omega\tau_1])?

7. Under conditions of Claim 15, if \zeta(t_1)\ne0, then from (2.185) \theta_i = \xi_i(t_1)/\zeta(t_1) immediately?

Despite the above mentioned remarks and questions, the thesis clearly merits to be positively evaluated.

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The thesis of A.O. Vedyakova “Methods of real-time parameter estimation for harmonic signals by delay introduction” fulfills the requirements established in the decree 01.09.2016 № 6821/1 on “Order of Granting Degrees in St. Petersburg State University”. A.O. Vedyakova deserves to be granted with the degree of Candidate of physical and mathematical sciences (Specialization 05.13.01 – System analysis, information control and processing). Clause 11 of the said decree has not been violated by the candidate for the degree.

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