Review on PhD thesis
Measures and LMIs for V&V of Adaptive Control
by Daniel Wagner

The PhD thesis of Daniel Wagner entitled "Measures and LMIs for V&V of Adaptive Control" is focused on the problem of verification and validation using the occupation measures and LMI-based relaxations in the field of aerospace. This PhD thesis consists of the collection of the authors the most relevant papers corresponding to the research field of interest. The thesis is well-written and has a clear structure. The document consists of 7 main chapters.

Chap.1 introduces the research field, briefly reviews the state-of-the-art in the optimization-based model reference adaptive control (MRAC) design and points out the main contributions of the PhD thesis. The main contribution in the theory is the novel control framework ensuring a finite-time convergence for non-autonomous systems. This framework guarantees that MRAC is robust enough to tolerate a sufficiently small unmodeled dynamics within the dynamical system. These unmodeled dynamics originate in the uncertain parameters of the system. The proposed control framework is based on the occupation measures and the sum-of-squares (SOS) hierarchies formulated using the relaxations via linear matrix inequalities (LMIs). The benefits and the properties of the proposed control framework were investigated in the Chaps.3-6 considering the set of case studies using the F-16 fight aircraft as the main benchmark.

Chap.2 summarizes the preliminaries and briefly formulates the control problem. Although this chapter covers all the crucial formulation of the considered optimization problems, the readability of the thesis will be improved, if Chap.2 would be more elaborated, e.g., there is missing a discussion, when Assumption 2.1.1 is satisfied, there is necessary some guesswork related to the introduced notation, etc. A very minor comment is related to the LMIs that are introduced in the title of the thesis, but they were not defined in the thesis.

Chap.3-6 reformulate the main results presented in the peer-reviewed papers published in the prestigious international conferences, such as IEEE Conference on Decision and Control (Chap.3), American Control Conference (Chap.4), or the results that been submitted into the AIAA Guidance, Navigation, and Control Conference (Chap.6), or the results submitted into International and Journal of Control [Q2, IF=2.780] (Chap.5).
Particularly, Chap.3 transforms a problem of a polynomial dynamical optimization into a problem of feasible moment SOS relaxation. In Chap.4, the approximation of the reference trajectory in MRAC is generated by exploiting the sparsity of ordinary differential equations. The constructed nonlinear model is validated. Chap. 5 designs the robust controller in the presence of the unmodeled flexible dynamics. Chap. 6 addressed the problem of MRAC designing subject to the uncertain higher-order actuator dynamics.

Chap.7 summarizes the main contributions of the PhD thesis and discuss some relevant open research problems. This reviewer understands that the presented contributions were achieved in the research group, but it would be beneficial, if there will be clearly pointed out the particular contributions of the author, e.g., the theoretical elaboration of the proposed control framework, corresponding software development, numerical validation and analysis of the generated results using the set of case studies, etc.

The PhD thesis studies the relevant research problem and provides the significant contributions. The presented results are highly relevant for the domain of the verification and validation in the field of aerospace.

The author's scientific results were published in 4 peer-reviewed conference papers, including the prestigious IEEE Conference on Decision and Control. The author has already submitted 2 more related conference papers that are under review. Finally, the author of this PhD thesis is a co-author of the Brief paper published in one of the most prestigious journals in the field of automation – Automatica [Q1, IF=6.583], that itself, depending on the level of his co-authorship, could qualify him for the PhD degree. Moreover, the author was awarded by the NASA-Missouri Space Grant Consortium (MOSGC) in 2017.

The author of the thesis proved to have an ability to perform research and to achieve scientific results. I do recommend the thesis for presentation with the aim of receiving a Ph.D. degree.

Questions:

Q1: One of the relevant competitive control strategies is a well-known model predictive control (MPC). MPC is not able (by default) to update the prediction model like it does the adaptive control framework. On the other hand, MPC outperforms other control strategies by taking into account various constraints. Would it be possible to implement the constraints on control inputs into the proposed control framework? Would it be possible to transform the proposed control framework into the discrete-time domain? What are the main limitations?

Q2: The PhD thesis often refers to the of-the-shelf-software packages, such as Gloptipoly toolbox and MOSEK/SeDuMi SDP solvers. But the thesis is missing the low-level formulation of the optimization problems in the form of the LMIs that are delegated into the SDP solver. Approximately, could you quantify the numerical complexity (number of LMI rows and number of scalar decision variables) for each optimization problem? From the computational point of view, what are the main limitations? The numerical complexity and problem tractability are briefly discussed in Sec.7.1, but could you be more specific, please?

Q3: In Chap.5, pp.42, the author refers to the MATLAB code entitled a "Validation Script" that is presented in the corresponding Appendix A. Does the author plant to write (or did he already write) some more general form of the code to make it suitable for solving the general class of the considered problem? It would be nice to have a (MATLAB) toolbox that enables solving the problem in a user-friendly way so that the user can focus on the analysis of the results instead of formulating the problem itself.

Bratislava, December 2, 2020

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