The Role of System Identification for Flight Vehicle Applications - Revisited

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1. SUMMARY

During the last few decades system identification methodology has been extensively used for flight vehicle modeling. This paper provides an overview of the basic methodology, highlighting the classical approaches and indicating a few current trends. Successful application of advanced aircraft parameter estimation methods has been demonstrated on a few challenging examples such as determination of aerodynamic effects of secondary importance, identification of highly augmented unstable or flexible aircraft, and high bandwidth rotorcraft modeling. The selected examples demonstrate that the system identification methods have reached a maturity level that makes them a powerful and indispensable tool to support not only research but also the industry activities in various key areas such as model validation, handling qualities evaluation, control law design, and flight vehicle design. Thus, it contributes significantly to risk and cost reduction in the optimal deployment of existing aircraft and in the development of new generation flight vehicles.

2. INTRODUCTION

During the last few decades there has been a constant effort in determining static as well as dynamic characteristics from flight test measurements. The coordinated approach encompassing flight test instrumentation, flight test techniques, and flight data analysis leads to a Quad-M (Motion, Measurements, Methods, and Models) concept of system identification [1]. It has resulted in generating sufficient practical experience to apply these techniques to diversified flight vehicle applications on a routine basis [1-3]. Today, the scope of applications ranges from the classical purpose of data correlation for increasing the confidence in flight mechanical prediction techniques to generating high fidelity aerodynamic databases, flight envelope expansion, high performance unstable aircraft, and high bandwidth rotorcraft modeling [1].

The full-fledged flight crew training simulators for commercial transport as well as high performance aircraft, in general, should demonstrate high fidelity, often meeting the Level D fidelity standards specified by the Federal Aviation Administration (FAA) [4,5]. Fidelity of flight simulation depends to a large extent on the accuracy of the aerodynamic database representing the aircraft. Furthermore, the demands of high-performance characteristics have led to aerodynamically unstable aircraft configurations, which can be flown only with the aid of flight controllers based on modern control concepts. In this case, it is mandatory that the aerodynamic characteristics used for control law design are representative of the actual aircraft.
To minimize the overall developmental costs, it is necessary to minimize the amount of costly and time consuming flight testing necessary for aircraft specification and certification requirements. Furthermore, the new aerodynamic design concepts such as, for example, thrust vectoring [6] or quasi-tailless aircraft [7], require careful expansion of the flight envelope through i) data correlation between the prediction and flight identified aerodynamic characteristics and ii) isolation and identification of non-anticipated aerodynamic effects. This is also true in the case of large flexible aircraft, where the structural modes can influence the aircraft response and the accuracy of flight mechanical models [8,9].

The philosophy of model-following control based on feed forward regulation provides safer and more accurate mode control; the performance, however, depends strongly on the validated mathematical model of the host flight vehicle [1,10]. For such an application, the rotorcraft flight control has to meet the high bandwidth requirements, demanding augmentation of the rigid-body model through higher-order rotor dynamics.

Thus, the present challenge to flight vehicle system identification may be formulated as to determine a high-fidelity aerodynamic model of a high performance, highly augmented vehicle from rapid, large amplitude maneuvers. Such a global model is, in general, of unknown structure, highly nonlinear, and affected by elastic modes, unsteady aerodynamics, and erroneous air data measurements. Although a general single shot solution to this problem may be difficult, significant advances have been made both in terms of aerodynamic modeling and aircraft parameter estimation methods. A brief account of the Quad-M approach is presented in this paper, indicating a few current trends and bringing out the salient features through typical examples for each of the four M. Model validation issues are briefly addressed. The paper then demonstrates that for each of the aforementioned flight vehicle applications the current system identification tools provide an adequate solution, enabling either an update of the predicted database or even generation of a comprehensive database/model valid over the operational flight envelope meeting the high accuracy demands. These examples bring out clearly the role of system identification for flight vehicle applications. It is evident from Fig. 1 that today these tools are an integral part of any aircraft development and assessment program.


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