***Discrete-Time Linear and Nonlinear Aerodynamic Impulse Responses for Efficient Use of CFD Analyses***

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Abstract

This dissertation discusses the mathematical existence and the numerically-correct identification of linear and nonlinear aerodynamic impulse response functions. Differences between continuous-time and discrete-time system theories, which permit the identification and efficient use of these functions, will be detailed. Important input/output definitions and the concept of linear and nonlinear systems with memory will also be discussed. It will be shown that indicial (step or steady) responses (such as Wagner's function), forced harmonic responses to random inputs (such as gusts) can all be obtained from an aerodynamic impulse response function. This will establish the aerodynamic impulse response function as the most fundamental, and, therefore, the most computationally efficient, aerodynamic function that can be extracted from any given discrete-time, aerodynamic system. The results presented in this paper help to unify the understanding of classical two-dimensional continuous-time theories with modern three-dimensional, discrete-time theories.

The Volterra theory of nonlinear systems is described and a discrete-time kernel identification technique is presented. The kernel identification technique is applied to a simple nonlinear circuit defined by a Riccati differential equation. The method is then applied to the nonlinear viscous Burger's equation as an example of an application to a simple CFD model. Finally, the method is applied to a three-dimensional aeroelastic model using the CAP-TSD (Computational Aeroelasticity Program – Transonic Small Disturbance) code and then to a two-dimensional model using the CFL3D Navier-Stokes code. Comparisons of accuracy and computational cost savings are presented. Because of its mathematical generality, and important attribute of this methodology is that it is applicable to a wide range of nonlinear, discrete-time problems.