Public Abstract
First Name:Xuewei
Middle Name:N/A
Last Name:Ruan
Adviser's First Name:Perngjin
Adviser's Last Name:Pai
Co-Adviser's First Name:N/A
Co-Adviser's Last Name:N/A
Graduation Term:SP 2014
Department:Mechanical & Aerospace Engineering
Degree:MS
Title:Parametric and Nonparametric Dynamical System Identification Using Laser-measured Velocities

Accurate damage inspection and reliable health monitoring of dynamical systems relies on accurate system identification techniques, where signal procession for accurate extraction of modal parameters from measured dynamical data plays the key role. In theory, if all three variables (i.e., displacement, velocity and acceleration) of each point on a dynamical system are available from measurement, parametric or even nonparametric system identification can be easily and accurately performed. In experiment, however, it is often only one variable is measured because collocating three different sensors at a point is too difficult even if the sensors are small enough not to affect the system's dynamic characteristics. Numerical investigations reveal that velocity is the best choice because the corresponding acceleration and displacement can be estimated by numerical differentiation and integration, and because today's laser vibrometers can provide very accurate measurements of velocities.

Real-world dynamical systems often behave nonlinearly especially when they are damaged or aged. Because dynamic characteristics (modal frequencies, damping ratios, mode shapes, etc.) of a nonlinear system change with time, system identification methods for nonlinear systems need to be capable of extracting such time-varying system characteristics and hence time-frequency analysis is essentially needed. Numerical investigation shows that direct time-domain methods based on processing of measured time-domain data can provide accurate identification results only for linear systems. Unfortunately, damping of a linear dynamical system cannot be accurately estimated by direct time-domain methods because its value is too small as compared to the values of stiffness and mass. Because frequency-domain methods are based on the use of frequency response functions from Fourier transform and conventional, linear modal testing techniques, they are also only valid for linear systems. On the other hand, indirect time-domain methods are based on the use of the maximum displacement and velocity states or the time-varying amplitudes and frequencies of responses to perform system identification. A nonparametric system identification method based on the use a spring force function of displacement and a damping force function of velocity or a combined restoring force function of displacement and velocity is developed and shown to work for any nonlinear systems.

All these direct time-domain methods, frequency-domain methods, and indirect time-domain methods are presented in this thesis, and advantages and shortcomings of each method are demonstrated and discussed through numerical examples. This thesis concentrates on the nonparametric system identification and presents several numerical techniques for noise filtering. Except numerical examples, experimental vibration data of a beam and a plastic car measured using a PSV-200 scanning laser vibrometer are also used to verify the accuracy of these methods.