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Nonlinear Stochastic Response of Marine Vehicles

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by

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Abstract

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The dynamic behavior of marine vehicles in extreme sea states is a matter of great concern following some recent and dramatic accidents. The complex problem of its prediction can be approached through the study, yet of broader scope, of nonlinear dynamic systems driven by stochastic processes.

Nonlinear statistical dynamics is a relatively new and difficult field. Although the diversity of techniques now available may seem fostering, the achievement of a unified and general theory for nonlinear response to stochastic process appears as a quite remote event.

Second-order statistics contain the most important information to describe a random process. Both theoretical and empirical evidence showing the superiority of the method of equivalent linearization to predict second-order statistics are exhibited and exemplified. The rationale underlying the Wiener-Hermite functional model appears to

further support this affirmation.

However, higher-order statistics cannot be accurately predicted within the framework of this technique whenever deviation from normal behavior becomes significant. A new technique for predicting the response moments and cumulants of nonlinear systems is presented.

This technique relies upon the construction of a series of linear systems aimed at the prediction of the response statistics of a given order. Such linear systems are successively defined by linearizing the original nonlinear system and matching the Volterra functional model response statistics of the desired order. The linear system for predicting second-order statistics coincide with the one obtained using the method of equivalent linearization.

This technique is exemplified by a nonlinear system governed by the Duffing equation with linear plus cubic damping. Several innovative results related to the transfer functions and the response cumulant of Volterra series are exhibited and used in our model.

Response probability distributions can be constructed from knowledge of these statistical moments. Particular attention is devoted to the distribution of maximum entropy and its justification as a method of inference in such underdetermined moment problems.

Finally, several applications to the rigid body behavior of marine vehicles serve to assess the accuracy and the versatility of these techniques. Response distributions of maxima so predicted compare very well with exact solutions or time domain simulation estimates when no exact solution is available.