Computational Finite Element Analysis of a Nonlinear Dynamical System Incorporating Uncertainties

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Abstract:
The accurate simulation of nonlinear dynamic systems under uncertainty demands advanced computational mathematics, posing a major challenge for predictive engineering. This work introduces a numerical framework grounded in the Stochastic Finite Element Method (SFEM) to address this complexity. The core of our contribution lies in the development of sophisticated computational algorithms capable of systematically propagating uncertainties—from both model parameters and the governing equations themselves—through the entire system. This allows for a rigorous mathematical analysis of vibrational regimes, both linear and nonlinear, under realistic conditions of variability. The power of this mathematical approach is demonstrated through its application in a cutting-edge field: the modeling of equipment used in processing bioinputs product derivatives. In this context, our simulations track the temporal evolution of vibrational behavior, quantifying how uncertainties intrinsic to the manufacturing process interact with operational excitations. Consequently, this computational-mathematical framework provides a robust foundation for the reliability analysis and design of mechanical systems—from industrial reactors to precision bioprocessing equipment—operating in dynamic and uncertain environments.

Keywords:
Computational Modeling, Stochastic Finite Element Method, Uncertainty, Nonlinear Dynamical Systems.