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Dispersion-minimized mass for isogeometric analysis

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Abstract

We introduce the dispersion-minimized mass for isogeometric analysis to approximate the structural vibration, which we model as a second-order differential eigenvalue problem. The dispersion-minimized mass reduces the eigenvalue error significantly, from the optimum order of $2p$ to the superconvergence order of $2p+2$ for the p-th order isogeometric elements with maximum continuity, which in return leads to a more accurate method. We first establish the dispersion error, where the leading error term is explicitly written in terms of the stiffness and mass entries, for arbitrary polynomial order isogeometric elements. We derive the dispersion-minimized mass in one dimension by solving a p-dimensional local matrix problem for the p-th order approximation and then extend it to multiple dimensions on tensor-product grids. We show that the dispersion-minimized mass can also be obtained by approximating the mass matrix using optimally-blended quadratures. We generalize the lower order quadrature-blending results to arbitrary polynomial order isogeometric approximations as well as to arbitrary quadrature rules. Various numerical examples validate the eigenvalue and eigenfunction error estimates.

Keywords: isogeometric analysis, quadrature rule, optimal blending, eigenvalue, dispersion error, dispersion-minimized mass

1. Introduction

Isogeometric analysis is a widely-used numerical method introduced in 2005 [1, 2]. The motivation was to unify the finite element method with computer-aided design tools. Under the framework of classic Galerkin finite element methods, the isogeometric analysis uses B-splines or Non-uniform rational basis splines (NURBS) instead of using the Lagrange interpolation polynomials as its basis functions. These basis functions have higher continuity (smoother), which in return improve the numerical approximations of multiple real-life problems.

The authors in [3] used isogeometric analysis to study structural vibrations and wave propagation problems. Their spectrum analysis showed that isogeometric elements

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