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Adaptive Isogeometric analysis for plate vibrations: an efficient approach of local refinement based on hierarchical a posteriori error estimation

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Abstract

This paper presents a novel methodology of local adaptivity for the frequency-domain analysis of the vibrations of Reissner-Mindlin plates. The adaptive discretization is based on the recently developed Geometry Independent Field approximaTion (GIFT) framework, which may be seen as a generalisation of the Iso-Geometric Analysis (IGA). Within the GIFT framework, we describe the geometry of the structure exactly with NURBS (Non-Uniform Rational B-Splines), whilst independently employing Polynomial splines over Hierarchical T-meshes (PHT)-splines to represent the solution field. The proposed strategy of local adaptivity, wherein a posteriori error estimators are computed based on inexpensive hierarchical $h-$refinement, aims to control the discretisation error within a frequency band. The approach sweeps from lower to higher frequencies, refining the mesh appropriately so that each of the free vibration mode within the targeted frequency band is sufficiently resolved. Through several numerical examples, we show that the GIFT framework is a powerful and versatile tool to perform local adaptivity in structural dynamics. We also show that the proposed adaptive local $h-$refinement scheme allows us to achieve significantly faster convergence rates than a uniform $h-$refinement.

Keywords: isogeometric analysis, PHT splines, error estimation, adaptivity, free vibrations

1. Introduction

Isogeometric analysis (IGA) was proposed in [1] to integrate Computer Aided Design (CAD) and analysis in Computer Aided Engineering (CAE). Due to the high continuity order of NURBS basic functions [1, 2], NURBS-based IGA has been successfully used to investigate many problems, and in particular problems related to plate vibrations, including Kirchoff plate [3, 4] and ReissnerMindlin plate [5, 6]). The results obtained when using IGA are often more accurate than those obtained using the traditional finite element method (FEM). The previously mentioned studies of plate vibrations with IGA are mostly dedicated to homogeneous structures, whereby the vibrations occur globally so that the uniform refinement of NURBS is an adequate method to control the discretisation error. However, when the dynamic solution exhibits local features, due to e.g. sharp geometrical features and/or varying material properties, the uniform NURBS-based refinement may become inefficient. This is because NURBS basis functions in 2D and 3D have tensor product form, which leads to globally structured grids (see Fig.1(a)), which in turns result in computational wastage when trying to capture the local features of interest.

To overcome these limitations, splines with local refinement properties such as (truncated) hierarchical B-splines [7, 8], hierarchical NURBS [9], locally refined (LR) B-splines [10], T-splines [11, 12], and polynomial/rational splines over hierarchical T-meshes (PHT/RHT)-splines [13, 14] were developed. In this study, we choose to apply PHT-splines, as they inherit the main merits of both B-splines and T-splines: basis functions can be represented by Bezier-Bernstein polynomials over a set of Hermite finite elements, and mesh refinement is local and simple (as seen in Fig.1(b)). In the recent past, PHT-splines have been successfully used to solve static elastic solid problems. The numerical results of [14] showed that the adaptive PHT refinement delivers a

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