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# Scaled boundary polygons for linear elastodynamics

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## Abstract

A polygonal scaled boundary finite element method (SBFEM) is proposed for linear elastodynamics in two dimensions. The domain is divided into non-overlapping polygonal elements, and the scaled boundary finite element approach is employed over each polygon. The advantages are that an arbitrary interpolation order can be used on each polygon and we can choose the optimal element order on each edge individually. Moreover, the SBFEM simplifies the numerical integration over the polygons when compared to conventional approaches. The dynamic stiffness matrix is computed by employing the continued fraction expansion. The influence of the shape of the polygon and the element order on the boundary of each polygon are studied. The robustness and the accuracy of the approach are demonstrated with numerical examples.

*Keywords:* SBFEM; Scaled boundary polygons; polygonal elements; wave propagation; elastodynamics.

## 1. Introduction

The finite element method (FEM) relies on an a priori definition of a topological map, called a 'mesh'. A mesh is a set of individual non-overlapping regions called 'elements'. Typically the shapes of the elements are restricted to triangles or quadrilaterals in two dimensions. This poses challenges in automating the meshing task. Moreover, when employing the FEM for time-dependent phenomena, typically, a semi-discretization scheme is adopted, wherein: (a) finite elements are used in space to reduce the partial differential equations in space and time to a system of ordinary differential equations in time and (b) time-stepping procedures based on finite difference approximations are employed for solving the ordinary differential equations.

Other approaches are based on the space-time finite element method [1] and mixed finite element methods [2]. The FEM converges, in general, to a reference solution when decreasing the element size. In case of time-dependent problems, the adequate element size depends on the frequency. Hence for mid and high-frequency problems, the FEM would require a very fine mesh, which directly influences the computational complexity and costs. Moreover, geometric discontinuities such as cracks or material interfaces increase the complexity and slow down the convergence rate.

In a continued effort to improve the quality of the finite element solution, recent research has focused on relaxing the topological constraints by allowing elements to take arbitrary shape and size. This has led to the development of the polygonal finite element method (PFEM) [3–5]. The PFEM also aids in local refinement and/or coarsening [6, 7] in a natural way such that it can facilitate the implementation of contact conditions

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