

Evaluating singular and near-singular integrals on C^2 smooth surfaces with a novel geometric method and closed form expressions

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Abstract

Most Fredholm integral equations involve integrals with weakly singular kernels. Once the domain of integration is discretized into elements, these weakly singular kernels become strongly singular or “near-singular”. Common methods to compute these integrals when the kernel is a Green’s function include the Duffy transform, polar coordinates with closed analytic formulas, and singularity extraction. However, these methods do not generalize well to the normal derivatives of Green’s functions. We provide methods to integrate both the Green’s function and its normal derivative on smooth surfaces discretized by triangular elements in three dimensions. For strongly singular integrals involving normal derivatives of Green’s functions, we provide two methods that can accurately approximate the true integrals on the true domain. The Geometric method uses geometric information of the true surface of integration to approximate the original integral on the true domain using push-forward maps. The Interpolation-Duffy method heuristically cancels out the singularity and then evaluates the integral using a quadrature scheme. Both methods are better than simply setting the singular integrals to zero, while being faster than adaptive refinement methods. The explicit analytic formulas for integrating polynomials p of degree less than three are provided.

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