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A user-friendly method for computing indefinite integrals of oscillatory functions

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Abstract

For indefinite integrals $Q(f;x,\omega) = \int_{-1}^{x} f(t)e^{i\omega t}dt$ $(x \in [-1,1])$ Torii and the first author (1987) developed a quadrature method of Clenshaw-Curtis (C-C) type. Its improvement was made and combined with Sidi's mW-transformation by Sidi and the first author (1996) to compute infinite oscillatory integrals. The improved method per se, however, has not been elucidated in its attractive features, which here we reveal with new results and its detailed algorithm. A comparison with a method of C-C type for definite integrals $Q(f;1,\omega)$ due to Domínguez, Graham and Smyshlyaev (2011) suggests that a smaller number of computations is required in our method. This is achieved by exploiting recurrence and normalization relations and their associated linear system. We show their convergence and stability properties and give a verified truncation error bound for a result computed from the linear system with finite dimension. For $f(z)$ analytic on and inside an ellipse in the complex plane z the error of the approximation to $Q(f;x,\omega)$ of the improved method is shown to be bounded uniformly. Numerical examples illustrate the stability and performance of the method.

Keywords: quadrature rule, algorithm, oscillatory integral, Chebyshev interpolation, error analysis, uniform approximation, three-term recurrence

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