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Loop integral computation in the Euclidean or physical kinematical region using numerical integration and extrapolation

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The computation of loop integrals is required in high energy physics to account for higher-order corrections of the interaction cross section in perturbative quantum field theory. Depending on internal masses and external momenta, loop integrals may suffer from singularities where the integrand denominator vanishes at the boundaries, and/or in the interior of the integration domain (for physical kinematics).

In previous work we implemented iterated integration numerically using one- or low-dimensional adaptive integration algorithms in subsequent coordinate directions, enabling intensive subdivision in the vicinity of singularities. To handle a threshold singularity originating from a vanishing denominator in the interior of the domain, we add a term (for example, $i\delta$) in the denominator, and perform a nonlinear extrapolation to a sequence of integrals obtained for a (geometrically) decreasing sequence of δ.

In addition this may give rise to UV singularities, treated by dimensional regularization, where the space-time dimension $n = 4$ is replaced by $n = 4 - 2\varepsilon$ for a sequence of ε values, and a linear extrapolation is applied as ε tends to zero. Presence of both types of singularities may warrant a double extrapolation. In this paper we will devise and apply a strategy for loop integral computations by combining these methods as needed for a set of Feynman diagrams. In view of the compute-intensive nature, the code is further multi-threaded to run in a shared memory environment.

Significance

In view of the improvements in the technology of high energy physics experiments,
accurate theoretical predictions with higher-order corrections are required for an accurate
theoretical prediction of the cross-section for particle interactions.
Whereas symbolic or symbolic/numerical calculations are performed for some challenging
problems using existing software packages, we focus on the development of fully
numerical methods for the evaluation of Feynman loop integrals. The integration
strategies adhere to automatic integration, which is a black-box approach for generating
an approximation, assuming little or no knowledge of the problem, apart from the
specification of the integrand function. In this paper we apply and evaluate integration and extrapolation strategies for a set of Feynman diagrams.

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Experiment context, if any

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