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Methods for detecting saddle-type objects from spatio-temporal data: A comparative analysis

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The positions of saddle points and their associated invariant manifolds are known to play a crucial role in understanding transport processes in two-dimensional steady flows. Since the relevant data are often only coarsely gridded, a reliable detection of fixed points in spatio-temporal discretised vector fields is a problem of contemporary interest. Unsteady flows may additionally exhibit distinguished hyperbolic trajectories and associated manifolds - often only defined on a finite-time span - that continue to organise particle transport. As these objects are known to be Lagrangian their exact position can typically not be deduced from analysing single velocity fields.

In the literature, several methods are described for approximating hyperbolic objects in steady and unsteady flows, but it is usually not clear how well they perform for a specific data set. This contribution presents a comparative analysis of the performance of three common methods (finite-time Lyapunov exponents, hyperbolicity time, leaking). In addition, a simple statistic approach based on a gradient approximation of the velocity fields is used to approximate instantaneous stagnation points.

The results are evaluated with respect to the errors in the total number and location of analytically known saddle points for two different two-dimensional steady velocity fields. The reliability is statistically tested by applying multiplicative Gaussian white noise to the original data and repeating all procedures. In a second step of analysis, the different methods are applied to time-dependent versions of these velocity fields, where candidates for hyperbolic trajectories are detected and compared.