Nonlinear Sciences > Chaotic Dynamics

Detecting coherent structures using braids

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(Submitted on 11 Jun 2011 (v1), last revised 4 Oct 2011 (this version, v2))

The detection of coherent structures is an important problem in fluid dynamics, particularly in geophysical applications. For instance, knowledge of how regions of fluid are isolated from each other allows prediction of the ultimate fate of oil spills. Existing methods detect Lagrangian coherent structures, which are barriers to transport, by examining the stretching field as given by finite-time Lyapunov exponents. These methods are very effective when the velocity field is well-determined, but in many applications only a small number of flow trajectories are known, for example when dealing with oceanic float data. We introduce a topological method for detecting invariant regions based on a small set of trajectories. In the method we regard the two-dimensional trajectory data as a braid in three dimensions, with time being the third coordinate. Invariant regions then correspond to trajectories that travel together and do not entangle other trajectories. We detect these regions by examining the growth of hypothetical loops surrounding sets of trajectories, and searching for loops that show negligible growth.

Comments:	23 pages, 22 figures. PDFLaTeX with RevTeX4-1 format. Minor corrections to the text
Subjects:	**Chaotic Dynamics (nlin.CD)**; Dynamical Systems (math.DS); Fluid Dynamics (physics.flu-dyn); Geophysics (physics.geo-ph)
Cite as:	**arXiv:1106.2231 [nlin.CD]** (or **arXiv:1106.2231v2 [nlin.CD]** for this version)

Submission history

From: Jean-Luc Thiffeault [view email]
[v1] Sat, 11 Jun 2011 12:20:38 GMT (710kb,D)
[v2] Tue, 4 Oct 2011 13:14:44 GMT (567kb,D)

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