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Field reconstruction using manifold learning and structure-preserving metrics

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The problem of estimating the state of a physical system is ubiquitous in science. However observations are always limited so that the high-dimensional state cannot be observed and the associated mathematical problem is ill-posed. Popular workarounds include dimension reduction and regularization by imposing some structure to the class of elements in which the estimation is sought.

We here rely on a purely data-driven approach and learn the map between extended measurements and the nonlinear manifold the state vector lies on. Specifically, we use embedding to address the non-Markovianity of the raw measurements. Combined with multi-kernel learning, it results in high-dimensional measurement features. The state vector nonlinear manifold is approximated and the map from measurement features to the estimated state is the solution to a Sylvester equation.

The methodology is illustrated with the estimation of a fluid flow field from a few wall-mounted sensors.

Orateur: Dr MATHELIN, Lionel (LIMSI-CNRS)