Higher Order Dynamic Mode Decomposition

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Standard dynamic mode decomposition (DMD) was introduced by Schmid (2010) using seminal ideas by Koopman (1931). This is a very useful method to post-process spatio-temporal data (resulting from generally nonlinear dynamics) as an expansion of spatial modes times exponentials in the time variable (to be called Fourier-like expansion), which exhibit generally nonzero growth rates. As such, DMD is an advantageous alternative to more classical methods to obtain such expansions (with zero growth rates), such as fast Fourier transform or power spectral density. However, standard DMD does not always give the correct results, even in cases in which the provided data admit an exact Fourier-like expansion. A recent method by the authors (2017), called higher order DMD (HODMD), solves this difficulty by essentially applying standard DMD to a set of enlarged snapshots that also contains time-delayed snapshots. Thus, HODMD synergically combines standard DMD and direct consequences of the well-known Takens' delay embedding theorem (1981). The new method will be illustrated using some toy-model dynamics and its performance will be tested using both, numerically generated databases from various nonlinear dynamical systems (complex Ginzburg-Landau equation, thermal convection in rotating spherical shells, cylinder wake) and experimental PIV measurements (zero-net-mass-flux jet and confined non-isothermal flows around vortex promoters). Some preliminary results on nuclear magnetic resonance data will also be presented.