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Cluster-based network model HAO LI, Scicence and Technology on Scramjet Laboratory, National University of Defense Technology, Changsha 410073,China, DANIEL FERNEX, RICHARD SEMAAN, Institut für Strömungsmechanik, Technische Universität Braunschweig, Braunschweig, Germany, JIANGUO TAN, Scicence and Technology on Scramjet Laboratory, National University of Defense Technology, Changsha 410073,China, MAREK MORZYNSKI, Chair of Virtual Engineering, Poznań University of Technology, Poznań, Poland, BERND R. NOACK, Center of Turbulence Control, Harbin Institute of Technology, Shenzhen 518058, China — We propose an automatable data-driven methodology for robust nonlinear reduced-order modelling from time-resolved snapshot data. In the kinematical coarse-graining, the snap-shots are clustered into few centroids representable for the whole ensemble. The dynamics is conceptualized as a directed network, where the centroids represent nodes and the directed edges denote possible finite-time transitions. The transition probabilities and times are inferred from the snapshot data. The resulting cluster-based network model constitutes a deterministic-stochastic grey-box model resolving the coherent-structure evolution. This model is motivated by limit-cycle dynamics, illustrated for the chaotic Lorenz attractor and successfully demonstrated for the laminar two-dimensional mixing layer featuring Kelvin-Helmholtz vortices and vortex pairing, and for an actuated turbulent boundary layer with complex dynamics. Cluster-based network modelling opens a promising new avenue with unique advantages over other model-order reductions based on clustering or proper orthogonal decomposition.

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