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On Visualizing Continuous Turbulence Scales

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Abstract: Turbulent flows are multi-scale with vortices spanning a wide range of scales continuously. Due to such complexities, turbulence scales are particularly difficult to analyse and visualize. In this work, we present a novel and efficient optimization-based method for continuous-scale turbulence structure visualization with scale decomposition directly in the Kolmogorov energy spectrum. To achieve this, we first derive a new analytical objective function based on integration approximation. Using this new formulation, we can significantly improve the efficiency of the underlying optimization process and obtain the desired filter in the Kolmogorov energy spectrum for scale decomposition. More importantly, such a decomposition allows a 'continuous-scale visualization' that enables us to efficiently explore the decomposed turbulence scales and further analyse the turbulence structures in a continuous manner. With our approach, we can present scale visualizations of direct numerical simulation data sets continuously over the scale domain for both isotropic and boundary layer turbulent flows. Compared with previous works on multi-scale turbulence analysis and visualization, our method is highly flexible and efficient in generating scale decomposition and visualization results. The application of the proposed technique to both isotropic and boundary layer turbulence data sets verifies the capability of our technique to produce desirable scale visualization results.

Projected Field Similarity for Comparative Visualization of Multi-Run Multi-Field Time-Varying Spatial Data

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Abstract. The purpose of multi-run simulations is often to capture the variability of the output with respect to different initial settings. Comparative analysis of multi-run spatio-temporal simulation data requires us to investigate the differences in the dynamics of the simulations' changes over time. To capture the changes and differences, aggregated statistical information may often be insufficient, and it is desirable to capture the local differences between spatial data fields at different times and between different runs. To calculate the pairwise similarity between data fields, we generalize the concept of isosurface similarity from individual surfaces to entire fields and propose efficient computation strategies. The described approach can be applied considering a single scalar field for all simulation runs or can be generalized to a similarity measure capturing all data fields of a multi-field data set simultaneously. Given the field similarity, we use multi-dimensional scaling approaches to visualize the similarity in two-dimensional or three-dimensional projected views as well as plotting

one-dimensional similarity projections over time. Each simulation run is depicted as a polyline within the similarity maps. The overall visual analysis concept can be applied using our proposed field similarity or any other existing measure for field similarity. We evaluate our measure in comparison to popular existing measures for different configurations and discuss their advantages and limitations. We apply them to generate similarity maps for real-world data sets within the overall concept for comparative visualization of multi-run spatio-temporal data and discuss the results.