Understanding fluid dynamics through Euler Characteristic Surfaces

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SGT, 6.10.2021

Abstract. We introduce the idea of Euler Characteristic Surface as a multiparameter map of a dynamical system. While multiparameter persistent homology is well established in topological data analysis, Euler Characteristic based multiparameter analysis gives a theoretically simple and computationally cheap step in understanding dynamical systems such as fluid flow. The method is used by us to study the fluid dynamics of a drying droplet with suspended particles (microscopic polystyrene beads) as observed in an experiment. Experimental image data is converted to binary data through optimal thresholding using Euler characteristic curves. In order to do a multiscale analysis of the extracted image sequence, we introduce the concept of Euler Characteristic at a specific scale. This multiscale time evolution of the connectivity information of aggregates of polystyrene beads in water is summarized in a Euler Characteristic Surface, and subsequently in Euler Characteristic Level Curve plots. We introduce a metric between Euler Characteristic Surfaces as a possible similarity measure between two flow situations. The philosophy behind the topological tools developed here is to produce low dimensional signatures of dynamical systems that may be used to efficiently summarize and distinguish topological information in various types of flow situations.