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Multi-level Association Rules and Directed Graphs for the Lagrangian Analysis of the Mediterranean Ocean Forecasting System (MFS)

B. Petelin (1), V. Malacic (1), A. Malej (1), M. Kukar (2), and I. Kononenko (2)

(1) National Institute of Biology, Marine Biology Station, Ljubljana, Slovenia, (2) University of Ljubljana, Faculty of computer and information science, Ljubljana, Slovenia

The Lagrangian method is one of basic methods for modeling the transport of water parcels and the dispersion of biological species. Lagrangian data analysis uses various tools which include classical statistics; however, a visual inspection of individual trajectories is also important for a first sight of the underlying dynamics. The difficulty of the analysis of a large number of trajectories and its visual presentation implies the need for more sophisticated methods. In this study we propose a new methodology which includes data mining and different visualization techniques, namely, association rules and directed graphs. Association rules mining is a representative of unsupervised data mining methods, used to find interesting and important relationships between subsets of attributes in large databases. Oceanographic data exhibit strong spatial and temporal dependencies, so we have extended the basic association rules discovery to spatial and temporal association rules mining. In addition, we need efficient methods for the visualization of the rules and thus we suggest a novel method which uses multi-level graphs with different levels of space and time granularity. Moreover, we can intertwine the knowledge from various disciplines related to oceanography, e.g. marine ecology, and form the graphs of connections among quantities with different granularity and refinement. The motivation for our work comes from the modeling of marine meta-populations where the persistence of local populations strongly depends on the topology and cycles of the connectivity networks. The results of first experiments with the Lagrangian trajectories obtained from the climatologically averaged results of the Adriatic Sea Forecasting System (AFS) show many similarities with previous findings concerning the circulation in the Adriatic Sea, especially regarding the currents along the Italian coast and cyclonic circulation in the southern Adriatic. In this study we present a case study on several thousands of Lagrangian trajectories, obtained from the velocity fields of the currents from the numerical results of the Mediterranean Ocean Forecasting System (MFS) during the period 1999-2011. We show the multi-level graphs derived from the given mass of trajectories, and demonstrate the usefulness of the algorithms on these graphs for the discovery of information from different branches of science that are related to oceanography. The association rules mining of graphs reveals typical frequent substructures of ocean circulation and assists in the identification of similar patterns of circulation during different seasons and year spans. Additionally we use the Markov models to find the distribution of particles, i.e. biological species, and their most probable paths in the model domain after a given number of time intervals. The aforementioned models can also show the degree of connectivity between different regions in the area of study.