Visualization and Analysis of Flow Fields based on Clifford Convolution

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Abstract

Vector fields from flow visualization often contain millions of data values. It is obvious that a direct inspection of the data by the user is tedious. Therefore, an automated approach for the preselection of features is essential for a complete analysis of nontrivial flow fields. This thesis deals with automated detection, analysis, and visualization of flow features in vector fields based on techniques transfered from image processing. This work is build on rotation invariant template matching with Clifford convolution as developed in the diploma thesis of the author. A detailed analysis of the possibilities of this approach is done, and further techniques and algorithms up to a complete segmentation of vector fields are developed in the process.

One of the major contributions thereby is the definition of a Clifford Fourier transform in 2D and 3D, and the proof of a corresponding convolution theorem for the Clifford convolution as well as other major theorems. This Clifford Fourier transform allows a frequency analysis of vector fields and the behavior of vector-valued filters, as well as an acceleration of the convolution computation as a fast transform exists.

The depth and precision of flow field analysis based on template matching and Clifford convolution is studied in detail for a specific application, which are flow fields measured in the wake of a helicopter rotor. Determining the features and their parameters in this data is an important step for a better understanding of the observed flow. Specific techniques dealing with subpixel accuracy and the parameters to be determined are developed on the way. To regard the flow as a superposition of simpler features is a necessity for this application as close vortices influence each other. Convolution is a linear system, so it is suited for this kind of analysis. The suitability of other flow analysis and visualization methods for this task is studied here as well.

The knowledge and techniques developed for this work are brought together in the end to compute and visualize feature based segmentations of flow fields. The resulting visualizations display important structures of the flow and highlight the interesting features. Thus, a major step towards robust and automatic detection, analysis and visualization of flow fields is taken.