Introduction
Recent advances in computing and simulation technology allow the simulation of time dependent flows. These are flows where underlying velocity field changes over time. The simulations of time dependent flows are a more realistic approximation of natural phenomena and they represent an invaluable tool for scientists in numerous disciplines.
Flow visualization, a subfield of scientific visualization is one of several research communities which deals with analysis of flows. There are many methods for analyzing steady flows, but the extension to the time dependent case is not straightforward. The SemSeg project is a FET Open project which tries to come closer to a universal solution for a semantic segmentation of time dependent flows, it aims at the formulation of a sound theoretical mechanism to describe structural features in time-dependent flow.

Proposed Approach
Several approaches are being pursued in the project, such as methods based on the finite time Lyapunov exponent (FTLE), Vector Field Topology (VFT) based methods, or interactive visual analysis (IVA). Uncertainty visualization and interactive evaluation of various methods is helping in evaluating current results.

Vector field topology (VFT) is a well-established methodology for analyzing and visualizing velocity field datasets. Its power lies in the automatic and parameter-free extraction of flow structures that have proven meaningful in a wide range of application domains. Its limitation is the restriction to steady flow. In order to overcome this limitation, we proposed to use moving frames of reference for local application of VFT. We defined criteria for the optimal choice of such moving frames. We also present a technique to visualize global uncertainty in steady 3D vector fields using a topological approach. We start from an existing approach for the 2D case and extend this into 3D space. In addition we develop an acceleration strategy to detect sink and source distributions. As part of the approach, we introduce uncertain saddle and boundary switch connectors and provide algorithms to extract them. A popular alternative to VFT is based on the finite-time Lyapunov exponent (FTLE), a scalar quantity that have been shown to be in close relation to flow structures, so-called Lagrangian coherent structures (LCS). These structures can be visualized without an explicit ridge extraction step. Analyzing LCS and the related geometrical trajectory properties allows understanding of structure of time dependent flow phenomena. However, for further analysis such as the study of bifurcations, ridges are necessary. We compared several ridge definitions and developed a novel method which exploits properties of finite-time Lyapunov exponent fields. It avoids one order of numerical differentiation and results in higher quality ridge surfaces. In our recent work we also developed a filter that allows to distinguish between separation due to different flow directions and separation due to different flow speeds. The filter follows the geometric intuition behind the original definition of FTLE as described by Haller and uses information that is inherent to it. We demonstrate the effect of the proposed filtering on both synthetic and simulated data.

Selected Results
Visual analysis of the simulation results of a revolving door equipped with an air curtain. The warm air outlet (green) is placed in the floor along the interior opening of the door, two air intakes (red) are at the side of the cylinder.

Topology of uncertain vector fields. 1024 measurements of a flow around a backward facing step were used to create an uncertain vector field. A special property of uncertain vector fields is that uncertainty is transported along critical points, and is thus indicated in the map.

Interactive Visual Analysis. Besides automatic methods we pursue research on interactive exploration of unsteady flows. A snapshot from the analysis of an exhaust manifold data set from an automotive industry is shown here.

Selected References