FFI Forsvarets forskningsinstitutt

Visualization of vector- and tensor fields

Visualization and analysis of vector- and tensor fields in 3-d is challenging. Typical vectors have three components, whereas tensors can have 9 or more components. A standard way to visualize vector- and tensor fields is to use geometric objects like vector arrows and ellipsoids, called glyphs. For datasets consisting of more than for example 643 grid points, the resulting image can be too full of objects and thus less informative. This is called occlusion and clutter. New techniques are needed to visualize vector- and tensor fields from large datasets. One way to do this is to identify critical points for vector fields, or degenerate points for tensor fields.

Identifying local topology close to such points can provide valuable information about the properties of the fields. The critical point and the topology of the vector field in its neighborhood can be classified by the eigenvalues of the Jacobian of the field, for example in foci, saddles, and repelling/attracting nodes.

Tensor fields are more complex to represent than vector fields. For symmetric tensors, eigenvalues and eigenvectors may be used. The eigenvalues can be visualized as scalar fields, and selected eigenvectors can be used as initial values for field line integration (hyper field lines). Sometimes it is sufficient to draw lines or glyphs only in a few selected points to obtain a clear view. It may help to identify degenerate points. These are points where two or more eigenvalues are identical. The hyper field lines will intersect at the degenerate points. Neighboring hyper field lines can be classified by the pattern they make at tri-sector points, or wedge points. The classification is used in the tensor field visualization. If the tensors are symmetric, they can describe the metrics of a “meta space”. The properties of the tensors can then be obtained by studying the geometry of this ”meta space”.

Goal:
The techniques described above can be applied to vector/tensor data from for example fluid/structural mechanics, magneto-hydro/electro dynamics etc. By applying improved visualization techniques, we wish to gain increased physical understanding and knowledge about complex physical systems, like turbulent flow. An existing database of flow data, for instance Direct Numerical Simulation data from turbulent channel flow, will be used to experiment with these techniques. Of special interest are the properties of so-called structural tensors for turbulent flow.

Prerequisites:
The projects require basic knowledge in mathematical analysis, linear algebra and programming. Some background in fluid/continuum mechanics is an advantage, but not required. It is recommended to have taken courses in numerical simulation and/or visualization.

Level:
Master Thesis projects.

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Remarks:
The projects will be performed using computers at FFI. Existing hardware and software, including the visualization package VoluViz, are available for the students. Workstations with ”state of the art” graphics card are provided for the students. A large database of suitable simulation data is also available for the students.