SimVis: Interactive Visual Analysis of Large & Complex Time-Dependent Simulation Data

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Overview

• About SimVis GmbH
• Introduction to 3D/4D simulation data
• Visualization goals and related challenges
• SimVis overview
• Application example
• Demo
SimVis GmbH

- Spin-Off company founded 04-2008
- Task: further development of SimVis software & commercializing the software
- Office in Vienna, Austria
- Currently 4FTEs, planning to expand
- Tight collaboration with several research partners
3D-4D Simulation Data

- Generated by physical models
- Large number of application fields
  - Engineering
  - Medicine
  - Climate research
  - Meteorology
- Spatial simulation domain decomposed into cells
- If 4D: temporal decomposition into time steps
- For each cell at each time step different physical properties are simulated
3D-4D Simulation Data

• Simulation results
  – Grid geometry (may vary over time)
  – Scalar/Vector quantities per cell (per timestep)

• Data characteristics
  – multi-variate data
  – large data sets (cells * timesteps * dim.)
Visualization Goals

• numerical data visualization aims at supporting the tasks of
  – exploration
    • find certain characteristics about dataset
    • also check whether data appears to be valid
    • → tools should provide maximum flexibility
  – analysis
    • based on hypotheses
    • verification or falsification, further investigation
    • → tools must provide some sort of querying possibilities
  – presentation
    • present and communicate results and findings of analysis to others
    • usually reduces information to be shown
    • not interactivity, but high visual quality is major goal
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The SimVis approach presented here is mainly targeted towards interactive exploration and analysis tasks!
Challenges w.r.t. Simulation Data

• Occlusion/Cluttering because of spatiotemporal nature
• Many result dimensions (scalar/vector)
  – Difficult to explore/analyze
• Data size
  – Multiple gigabytes of data
  – Interactivity is important
Examples

- Large (25 Mio cells x 48 timesteps)
- Many Attributes
- Spatiotemporal

Interactive Visual Analysis of Simulated Hurricane Isabel

Video
Examples

• 2D time dependent
• Large number of timesteps (~1300)

Video
Examples

- Spatiotemporal
- Vector attributes

Video
Examples

• Complex unstructured grids
SimVis

• General features
  – Feature-based visualization
  – Attribute derivation

• InfoVis for scientific data
  – Focus+Context visualization
  – Interactive (smooth) brushing
  – Complex feature definition via
  – Multiple linked views
SimVis data

inter. feature spec.

DOI

feature-based visualization

F+C visualization
Feature-Based Visualization

- Selective rendering of interesting/salient structures in the data

Data Courtesy of Zuse Institut Berlin
Attribute Derivation

• Comprehensible ways to derive synthetic data dimensions from original data
  – data smoothing
  – derivative information
  – vortex extraction measures
  – local minima/maxima
  – gradient information

• Attribute derivation + brushing
  = access to complex features
Focus+Context Visualization

- Salient/interesting features as focus
- Remaining data as context for orientation
- Differentiation of focus and context via visual attributes
Focus+Context Visualization

Focus

temperature
Focus+Context Visualization

Context
Focus+Context Visualization

Focus + Context
Smooth Brushing

• In InfoVis data often categorical/discrete
• Simulation data distributed continuously over simulated domain
• Binary brushing frequently not suitable for smoothly distributed data
Smooth Brushing

Temperature $> 313.16 \text{ K}$
Smooth Brushing

Temperature > 313.1 K
Smooth Brushing

DOI Ramp Between 313.1 K and 313.16 K
Smooth Brushing
Smooth Brushing
Interactive Brushing and Multiple Views

• Move/alter/extend brush interactively
• Linked F&C views updated in real-time

Video
Feature Definition Language

- Used to represent an analysis session as a tree of boolean operations
- Store and reload sessions
- Apply to other data sets (comparison)

Compare to:
- Natural language
- DB query

In&out: XML

Example:
interesting are ... ...
flow regions where pressure is high AND velocity is high
Visual Exploration of Nasal Airflow

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Nasal Airflow

• Ear, Nose, and Throat (ENT) specialists have to assess nasal breathing
• Direct measurements within the nose not possible without disturbing flow
• Rhinomanometry is the only objective measurement of nasal airflow
  – Integral information on pressure gradient
  – Total flow / flow resistance

→ Thus, physiological function of the nose cannot be assessed sufficiently and therapeutic concepts are difficult to derive
→ Use CFD to simulate air flow
CFD-Model Definition

- Available data
  - CT scans
  - Rhinomanometry
  - Visual inspection

- Volumetric Meshing
  - Based on surface extracted from CT
  - Unstructured tetrahedral mesh in the interior
  - Multiple layers of triangular prisms near surface

- Multiple mesh resolutions tested
  → ~3.5 million elements
CFD-Model Definition

- Simulated quantities
  - Air flow
    - two different turbulence models
    - one in boundary vicinity, one in free flow regions
  - Temperature
  - Humidity
    - Relative
    - Absolute
Exploratory Visualization

• Explore data
  – Look at single data attributes
  – Explore interrelations between attributes

• Facilitate hypothesis
  – Look at individual features
  – Observe interrelations between features
Exploratory Visualization

• Example:
  – Warm and cold air
  – Video vis2009-1021_divx.avi
Exploratory Visualization

• Explore data with multiple views
Exploratory Visualization

- Hypothesis generation
Exploratory Visualization

• Hypothesis generation

![Image of warm/slow vortex region and Inferior Meatus with color-coded temperature]
Live Demo
Summary

+ **general approach** *(works with data from different fields)*
+ **very flexible** *(analysis adapts to user interests)*
+ **user in the loop** *(visual feedback, iterative refinement)*
+ **useful for exploration** *(as well as for analysis)*
+ **smooth feature boundaries** *(agrees with the nature of continuous data)*
+ **comprehensible** *(analysis in the terms of the users)*
Thank You!
Questions?

www.simvis.at

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If interested in internship/ diploma thesis contact me at: muigg@simvis.at