Reflections on Data Visualization

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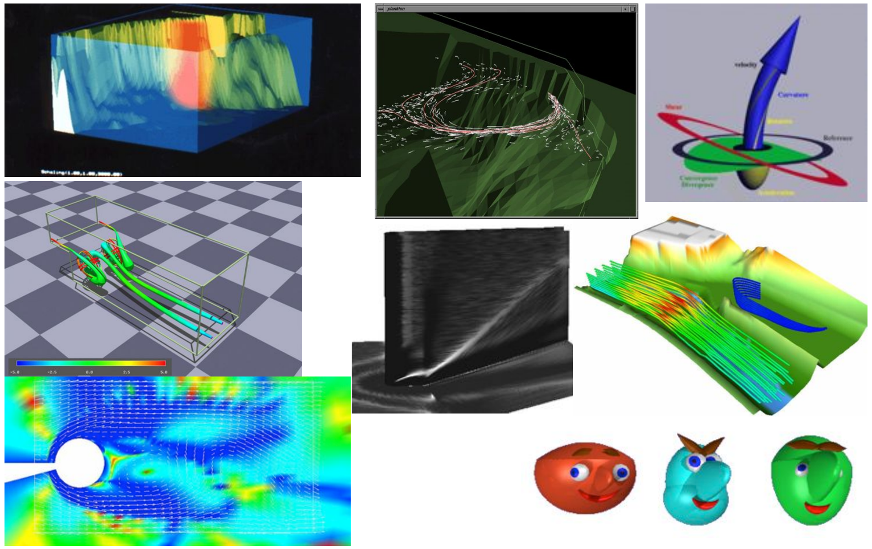
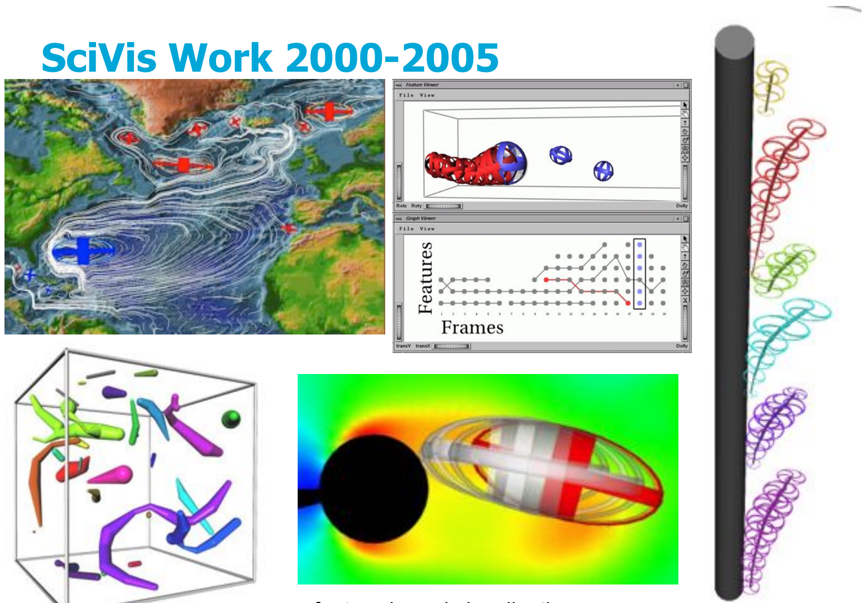
Overview

- short history
- current issues in visualization
- examples and reflections
- closing remarks

History: SciVis Work from the 1990s

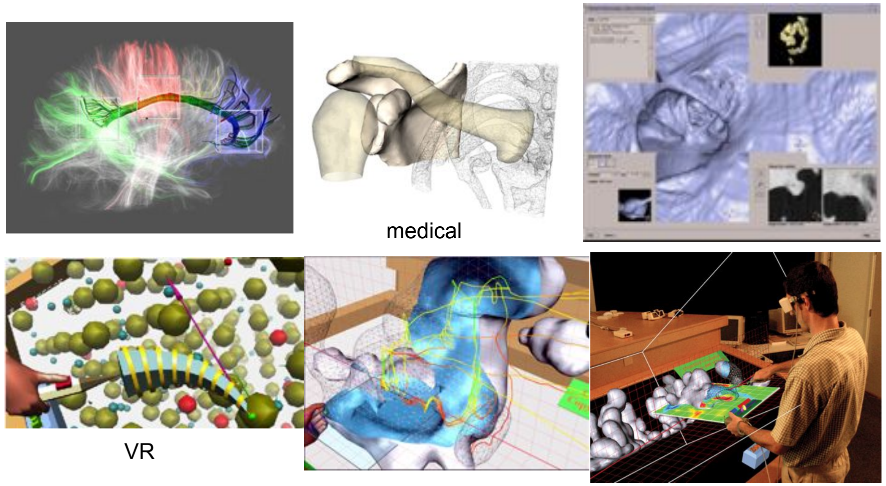


SciVis Work 2000-2005



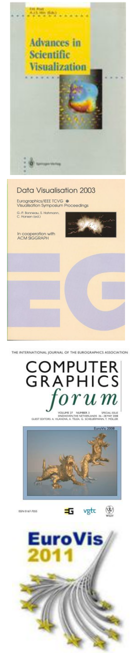
feature-based visualization

MedVis / VRVis Work 2000-2005

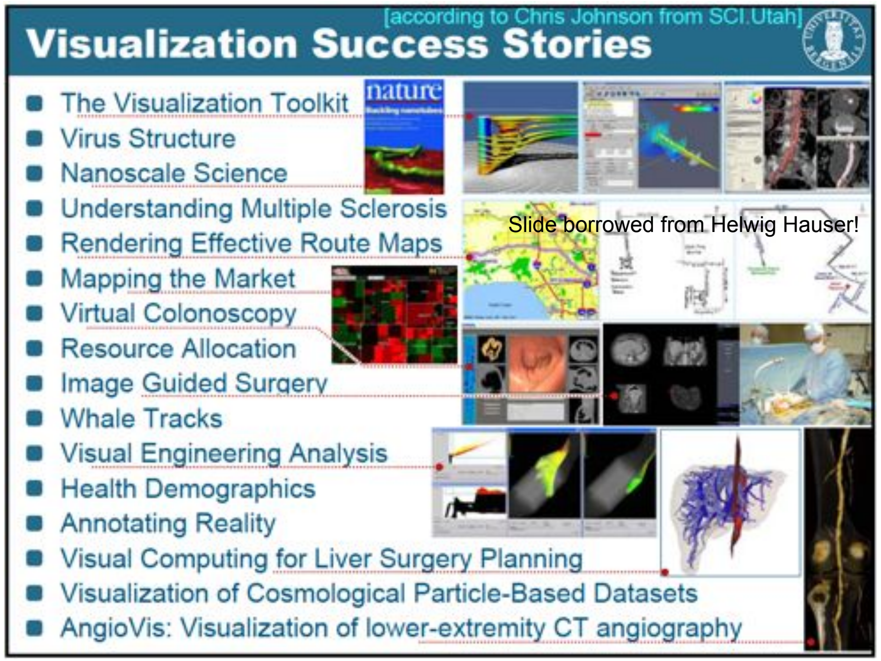


The Visualization Community: a one-slide history

- April 1990, Paris: 1st Eurographics Workshop on *Visualization in Scientific Computing*
- October 1990: 1st IEEE Visualization conference
- October 1995: 1st IEEE Information Visualization
- since 1998: collaboration with IEEE VGTC
- May 1999, Vienna: 1st EG/IEEE-VGTC *VisSym*
- June 2005, Leeds: EG/IEEE *EuroVis Symposium*
- from 2008: *EuroVis* proceedings published as special issue of *Computer Graphics Forum*
- May 31-June 3, 2011, Bergen, Norway: next *EuroVis* Symposium,190 papers submitted
- June 2012, Vienna: *EuroVis Conference!*



EuroVis+EGVE 2006, Lisbon



Current Issues & Trends - 1

- scalability: keeping up with the data deluge, and yet maintain interactivity
- high-dimensional data, abstract data spaces: integrating scivis + infovis + data analysis
- data documentation and accessibility, *data provenance*
- workflow and session management
- comparative visualization
- population variability, longitudinal studies

Current Issues & Trends - 2

- 3D interaction and HCI, usability
- demonstration, evaluation, validation of techniques
- towards generic methods: moving away from the *ad hoc*
- *uncertainty* visualization for decision making
- visualization for *communication* between user groups: scientists/engineers vs. policy makers vs. decision makers vs. general public

Examples and Reflections

1. Medical visualization: virtual colonoscopy
2. Visual Data Analysis
3. Integrating visualization
4. VR-visualization and atmospheric visualization
5. Video surveillance
6. Geodata and flooding protection

Virtual colonoscopy: visual inspection

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Unfolded cube: improved visibility with 360° view (Iwo Serlie, TU Delft)

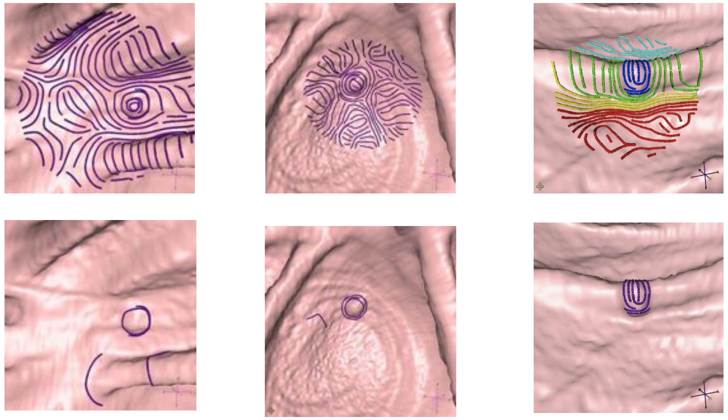
Virtual colonoscopy: Computer-Aided Diagnosis

- more effective visualization with 100% visibility of the surface
- BUT: visual inspection takes too much time for large-scale clinical use
- (semi)automatic pre-diagnosis needed: CAD
- use of vector field integration and feature detection for medical diagnosis
- automatic diagnosis must be visually confirmed, combining visualization and computer vision

Curvature lines for automatic polyp detection

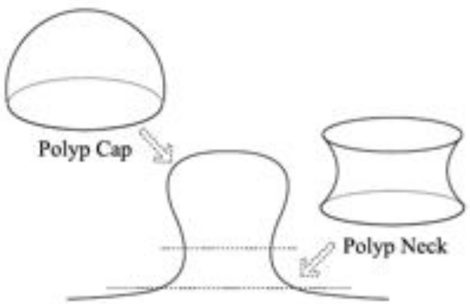
(Lingxiao Zhao, Charl Botha, Frits Post)

curvature lines: integral curves of principal curvature vector fields on the colon surface



closed curvature line | implicit isosurface | curvature line clustering

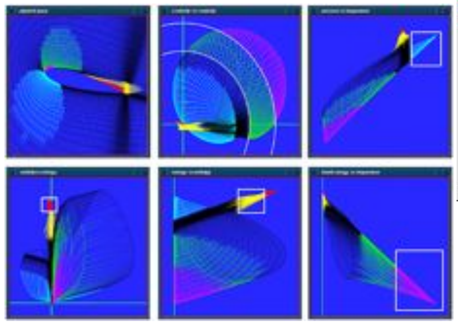
Idealized polyp model: cap and neck

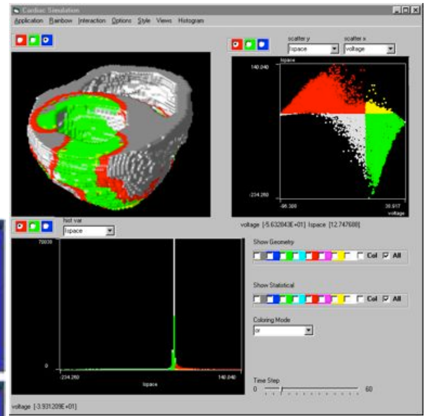


– polyp neck has negative Gaussian curvature
– closed curvature line around the neck
– winding-angle method (< vortex detection)

Interactive Visual Analysis: history

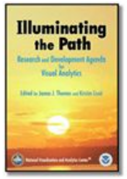
Linked-Derived Spaces – Chris Henze '98





WEAVE – Donna Gresh et al. '00

Visual Data Analysis / Interactive Visual Analysis



- Related to *Visual Analytics:*
  The science of analytical reasoning facilitated by interactive visual interfaces. [Thomas 2005]
- Iterative process: Information gathering, data preprocessing, knowledge representation, interaction, statistical analysis, and decision making.
- Goal: Extract *insight* from vast amounts of heterogeneous data by combining strengths of machines with those of humans: automatic analysis + visual perception [Keim 2006].
- Integral approach: Visualization + Human Factors + Statisitcal Data Analysis [Keim 2006]

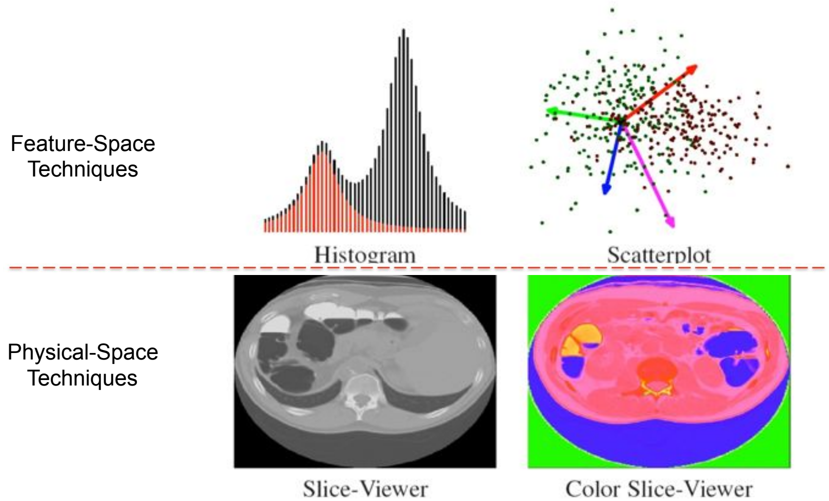
Visual Data Analysis - examples

- *MULTI:* a framework for multi-field data analysis [Blaas et al., EuroVis 2007]
- *Smooth Graphs:* exploring higher-order state sequences in multidimensional time series data [Blaas et al., Vis 2009]
- *Multi-Joint Kinematic Data:* visual analysis of motion data of human upper arm and torso [Krekel et al., EuroVis 2010]

MULTI framework
Jorik Blaas 2006

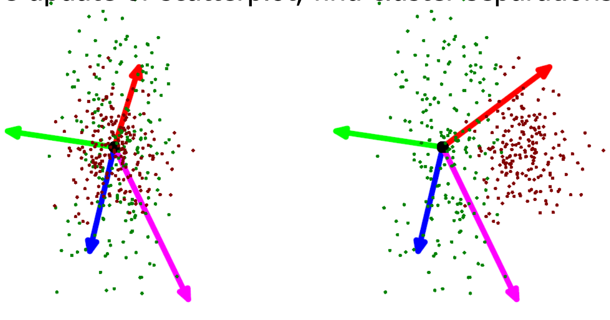
- exploring the high-dimensional data through dynamic linkage of physical space and abstract feature spaces
- for design of automated segmentation methods
- pattern recognition techniques in an interactive setting
- interface with multiple, dynamically linked views
- scatter plots with arbitrary projections of high-dim space
- interactive pattern analysis using PCA, LDA, kNN, …
- scalable up to tens of millions of data points

Viewing Components in MULTI



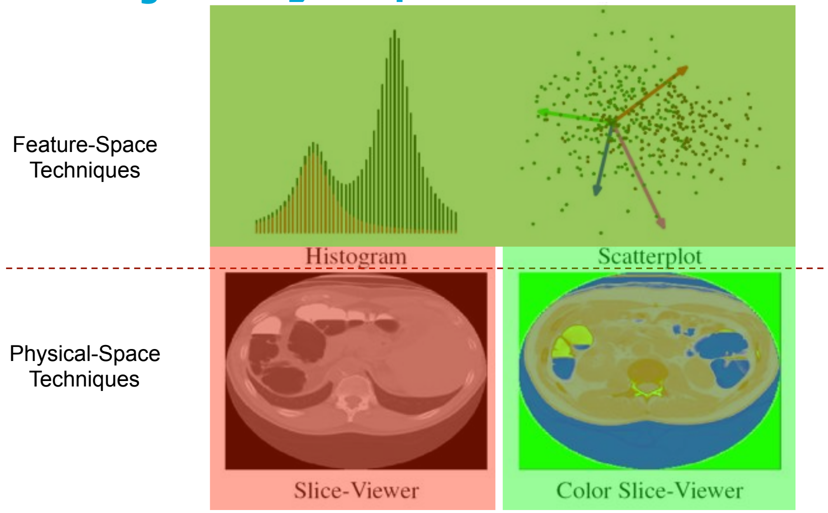
Increasing separation through projection

- projection plane spanned by two n-D vectors
- transform two n-D vectors into n 2-D vectors
- direct manipulation of each 2-D vector in projected view
- live update of scatterplot, find cluster separations



Original Projection   New Projection

Linking Viewing Components



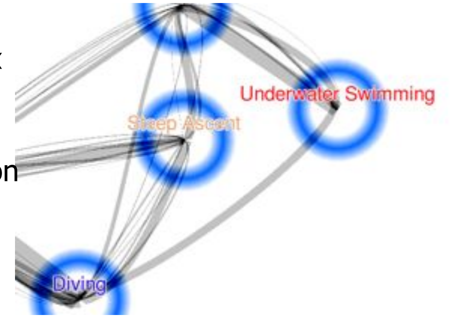
Linkage through Projections

Linkage through Selections

Smooth Graphs for Visual Exploration of Higher-Order State Transitions

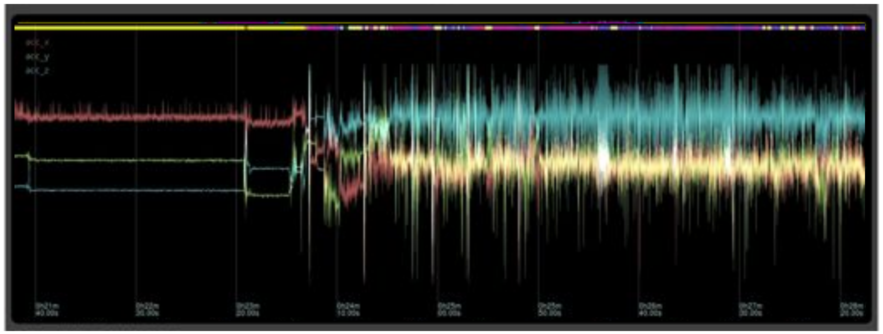
Jorik Blaas, Charl Botha, Edward Grundy, Mark W. Jones, Robert S. Laramee, Frits Post

- analysis of bio-sensor data attached to seabirds
- task is to derive complex behaviour patterns from basic data
- defined by state transition sequences of >2 states
- collaboration with Swansea vis group

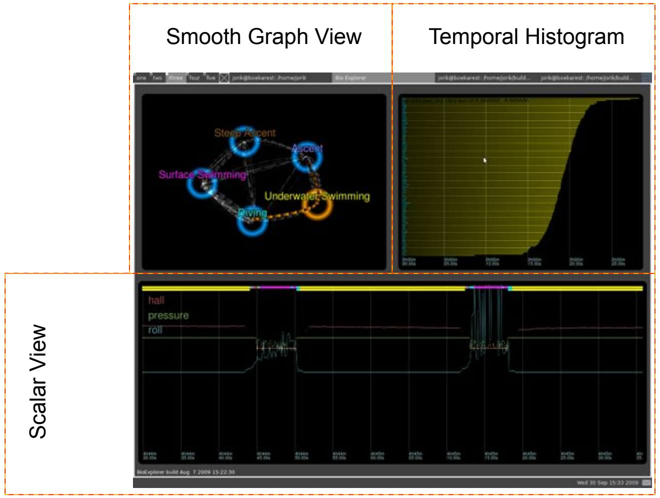


Data Acquisition

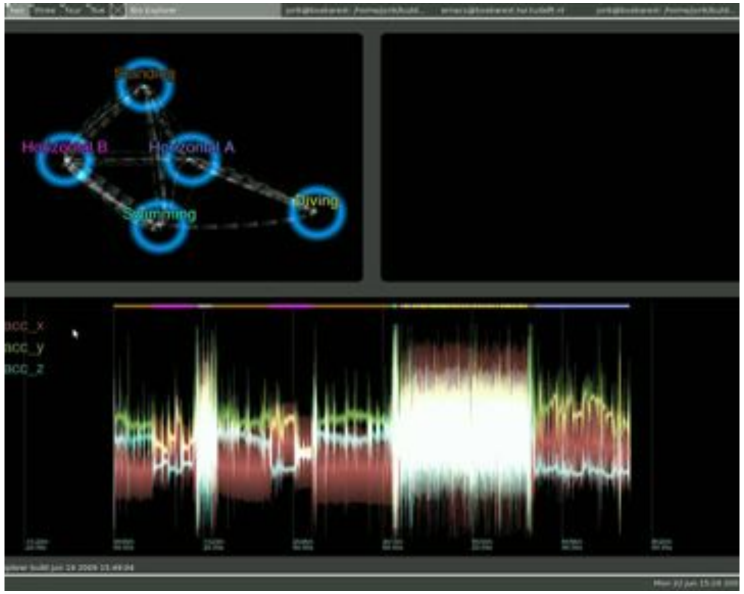
- bio-Sensors attached to animals (seabirds)
- measurement of Acceleration, pressure, roll, temperature, amount of light – no position!
- sampled at 10-20 Hz, over the course of several hours



User Interface



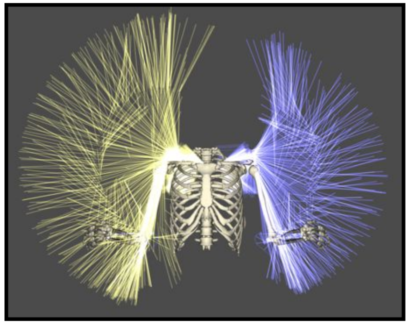
Demo



Visual Analysis of Multi-Joint Kinematic Data

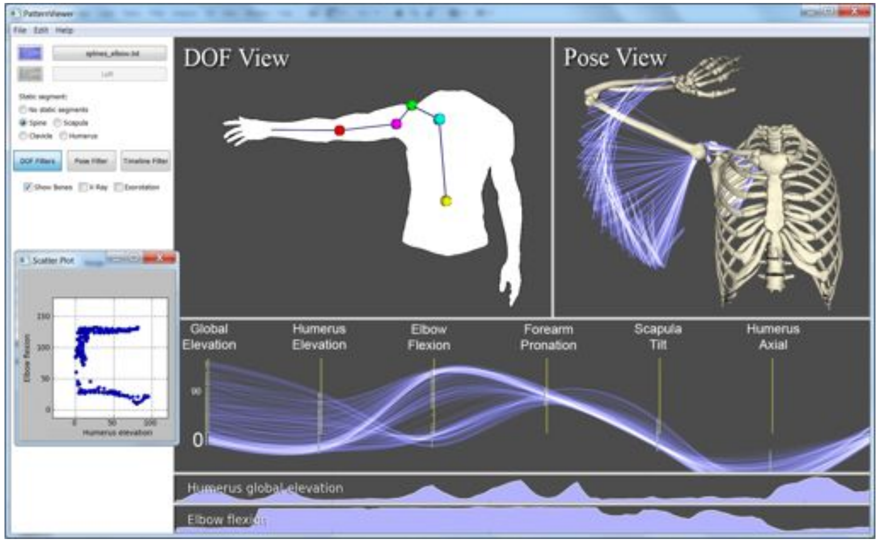
Peter Krekel, Edward Valstar, Jurriaan de Groot, Rob Nelissen, Frits Post, Charl Botha

- kinematic data describes the movement of limbs
- applications: orthopaedics, sports, rehabilitation medicine, biology
- mobility analysis
  - healthy vs. pathological
  - pre- vs. postoperative
  - evaluation of surgical treatment



LUMC

Overview



Multiple views

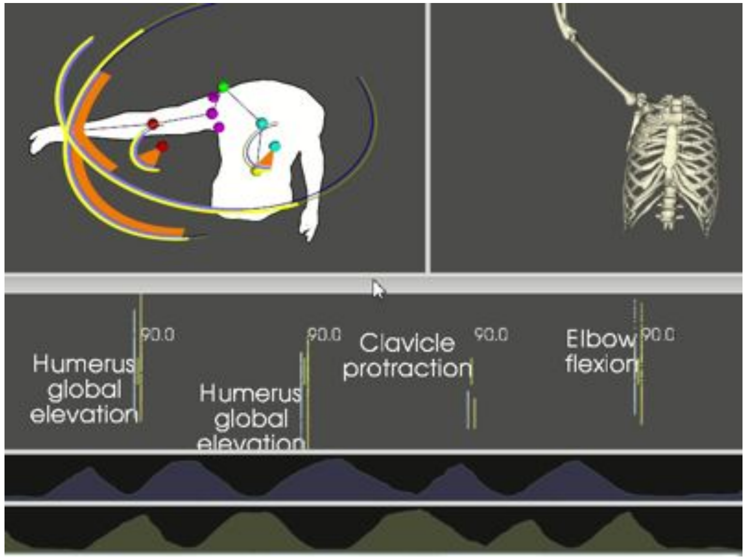
- DOF View: visualises the degrees of freedom of individual joints
- Pose View: visualises the complete joint chain of each recorded frame, and see trajectories of the joints
- Parallel Coordinates Plot: customisable in the DOF View – brushing + linking with Pose View
- n plots of values over time
- n scatterplots

Demo movie

DOF view pose view

PCP

time-series



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Reflections on VDA / IVA - 1

- multiple coordinated view interface with linking and brushing is a powerful *generic* visualization approach
- abstract spaces needed, for source and derived data, to augment spatial view (if any)
- strong interaction helps to promote insight
- advanced brushing in many different forms: fuzzy, angular, etc. for focus+context
- linking permits orientation and navigation in different views simultaneously

Reflections on VDA / IVA - 2

- integrated statistical analysis, pattern recognition, machine learning, …
- balance between human visual inspection and machine-based analysis and reasoning
- both visual and quantitative results
- used for low-level data analysis (classification, segmentation) and high-level feature detection
- features are application specific (eg. vortices in CFD) – need advanced modelling tools
- challenge: create general purpose environments for high-level analysis

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Interactive Visualization + VR

Examples:

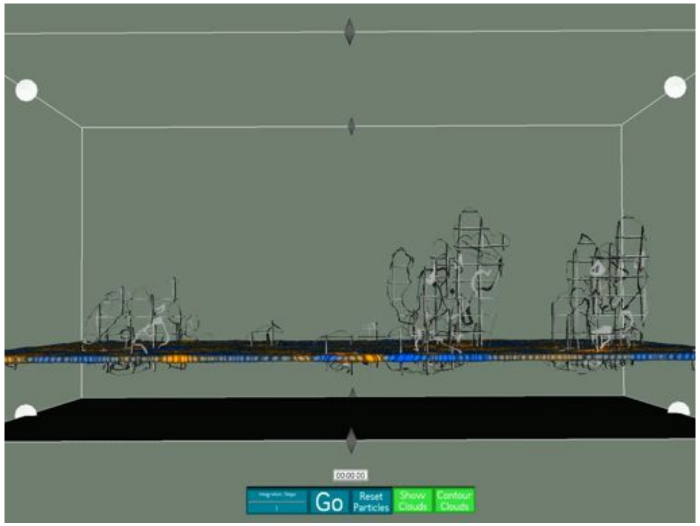
1. Interactive simulation/visualization for atmospheric physics:
   - particle tracing in time-varying data [Dussel, 2005/06]
   - cloud field exploration in virtual reality [Griffith 2008]
   - interactive atmospheric large-eddy simulation and visualization [Griffith 2009, Schalkwijk 2011]
2. video surveillance: visualization and navigation in multiple live video streams [De Haan, 2010]
3. landscape and visualization from large LiDAR point cloud and simulation data [De Haan, 2009-2011]
   - aerial LiDAR point clouds for landscape flythrough
   - integration of numerical flooding simulation data
   - web access to large landscape data

Particle tracing in time-varying atmospheric data
(Dylan Dussel, Eric Griffith, 2007)

GPU-accelerated particle tracing:

- interactive placement of a seed point volume
- GPU implementation
- over 1 million particles at > 20 fps
- 1st bottleneck: data loading from disk to GPU
- use vector field compression for higher bandwidth
- 2nd bottleneck: GPU memory (must contain at least one time step of data)

Interactive particle tracing in time-varying atmospheric data



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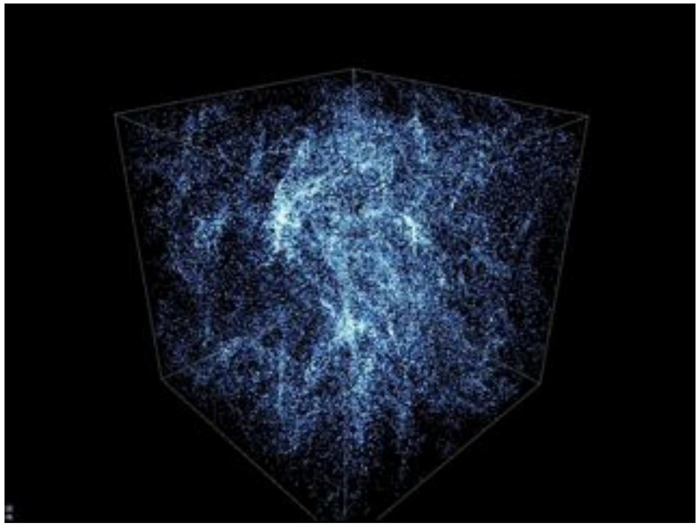
Droplet visualization: condensation



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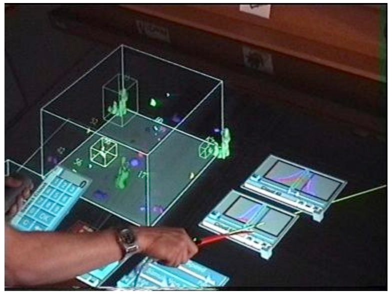
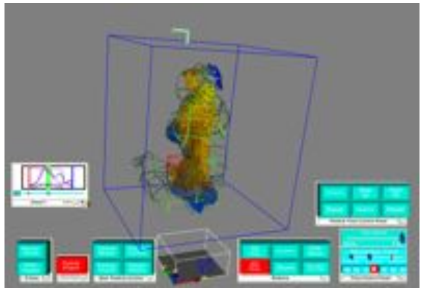
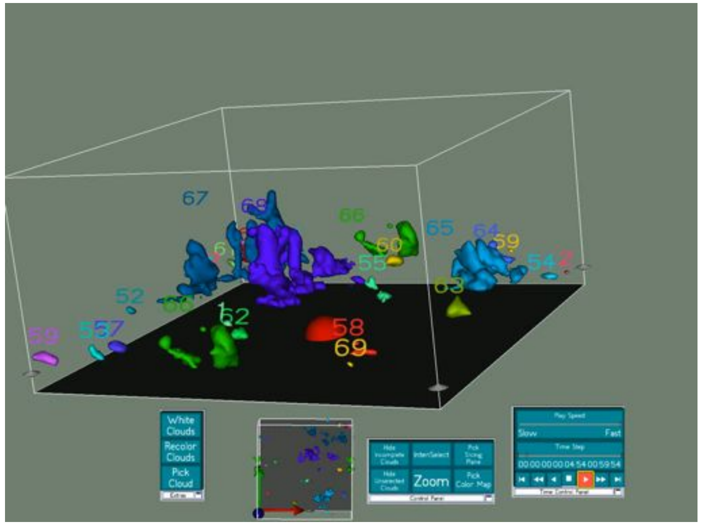
Cloud Explorer

- VR application for cumulus cloud life cycle studies: origin, development, decay
- focus on a single cloud: heat and moisture balance, air flow patterns
- hybrid 3D + 2D interface, reprocessing: VR equivalents of Visual Data Analysis!





Cloud Explorer



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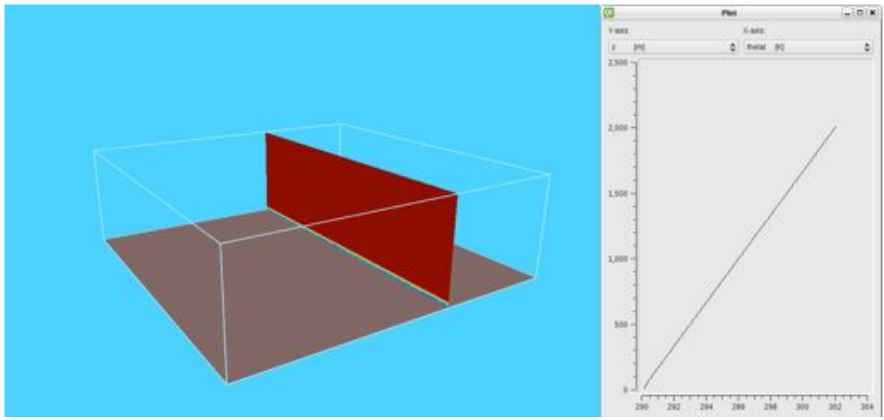
GALES: Interactive atmospheric Large-Eddy Simulation on a GPU

(Eric Griffith, Jerome Schalkwijk)

- full-scale turbulent atmospheric flow simulation
- GPU implementation in CUDA
- performance: 40% faster than existing LES running on one node with 32 processor cores of a supercomputer
- typically: < 4 min for 10K time steps on a 128×128×80 grid = 6h simulation time (on nVidia Tesla C1060)
- accuracy comparable to current batch oriented LES
- integrated visualization (volume + particle)
- interactive steering: adjust parameters, save and restore state, instant replay, live statistics, dynamic viewing

GALES: Interactive atmospheric Large-Eddy Simulation+visualization



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Reflections on Atmospheric Simulation and Visualization

- study of the turbulent boundary layer for better weather prediction and climate modelling
- cloud physics is essential for analysis of the earth's energy balance (amount of energy reflected by clouds)
- VR for focusing on single cloud and analysis of its temporal development (life cycle)
- GPU accelerated simulation (LES) is now feasible and now directly affects the workflow of the physicists
- large amounts of data NOT generated and stored (cheaper to repeat the simulation)

Video surveillance: visualization and interactive navigation

(Gerwin de Haan, Huib Piguillet)

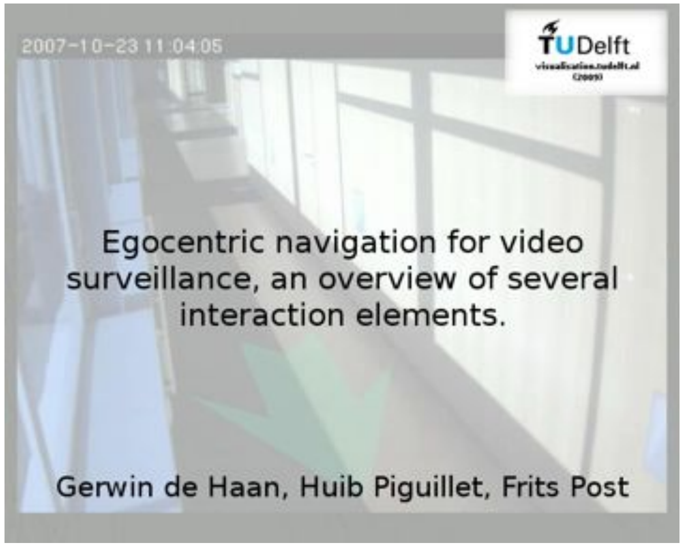
- visualization for live scene observation and guiding action
- *ego-centric* view and context awareness for task-oriented navigation (following persons or vehicles)
- integration with 3D environment geometry model with canvases placed in model
- smooth transitions between camera views
- active navigation with 3D scene widgets: icons for next camera view, 3D cursor for selecting a person

Video surveillance: visualization and navigation

video wall

ego-centric navigation

Video surveillance



Reflections

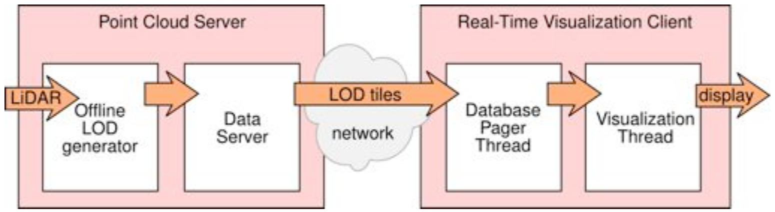
- current situation (video wall) does not scale to future needs
- coherent display needed for maintaining cognitive map
- active navigation is closer to field surveillance
- division of visual and automatic tasks:
  automatic person tracking / unusual event detection / visual verification
- challenge: event reconstruction = 'inverse storytelling': given the movie, find the story

Landscape visualization
Interactive flythrough of large landscape data bases
(Gerwin de Haan)

Very large point clouds of altimetric landscape data acquired with LiDAR on helicopter flights (AHN2 data set)

- 800 GB and still growing
- average density 20 points/m^2, countrywide coverage (NL)
- colour obtained from LiDAR or aerial photographs
- direct point rendering with levels of detail, needs preprocessing
- use of quadtree LOD tiling
- use of VRMeer™ library and OpenSceneGraph + Virtual Planet Builder

Landscape visualization
Interactive flythrough of large landscape data bases



- direct interactive visualization, optional stereo
- space-mouse navigation for flythrough
- 200 AHN tiles (~ 20 Mpoints/tile), 5 billion points at 30 fps
- used as setting for environmental hydrodynamic simulations such as flooding, water quality, and flow
- applications: water protection policy development, climate change adaptation measures, emergency management, …

Landscape visualization with AHN2

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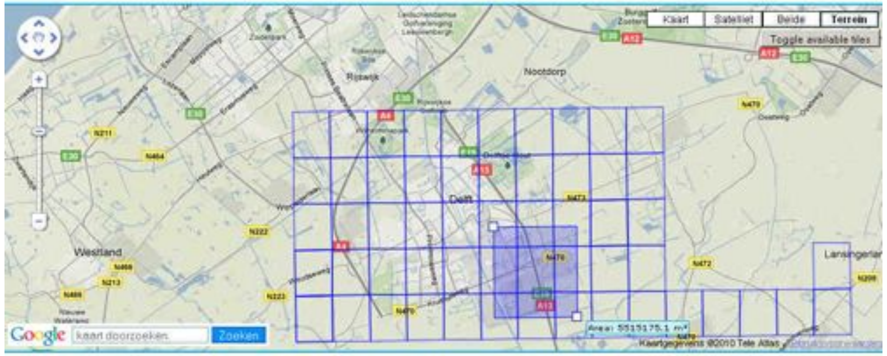
Access to AHN data via web interface



Velas3D AHN2 Selector (2009):
– web interface for access to tiles of AHN data
– use of Google Maps selection interface
– remote preprocessing, streaming to visualization client

CloudViewer: Web-based previewing of AHN data

- CloudViewer prototype web interface (2010)
- Google Maps pseudo-3D view + AHN point cloud as context
- define object view in 2D (circle)
- define 3D camera view angle above ground
- retrieve AHN data on server
- automatically generate flythrough movie

Flooding visualization in landscape

Reflections

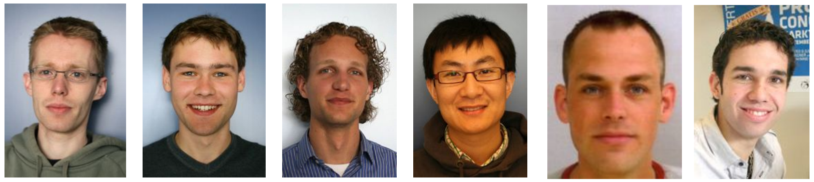
- interactive flythrough of real complex worlds: strong impact if we see our own neighborhood or town
- remote access to huge public data bases urgently needed – but no data duplication + network transport
- direct communication between user groups: scientists/ engineers, policy developers, decision makers, general public
- mixing static landscape data and dynamic simulated data (eg. flooding, earthquakes) needed for disaster studies and long-term protective policies
- challenge: extract geometry of buildings etc. and intermix with point clouds

Final Remarks

- some examples of recent work in visualization and how it relates to the current issues
- greatest success story of the field: closing the scale gap, and going interactive in all applications
- visualization can make a difference:
  - to affect the workflow of scientists, engineers, and other professionals
  - be involved in policy development and decision making
  - help to communicate complex issues to mixed audiences

Thanks to the TUD Data Vis Group...

Jorik Blaas | Charl Botha | Stef Busking | Gerwin de Haan | Eric Griffith | Frits Post



Peter Kok | François Malan | Peter Krekel | Lingxiao Zhao | Thomas Kroes | Jerome Schalkwijk

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- you, the audience, for listening
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- NWO project Visualization of Cumulus Clouds in VR
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- Philips Healthcare, CT Colonography project
- Knowledge for Climate Foundation
- 3D Water Management project