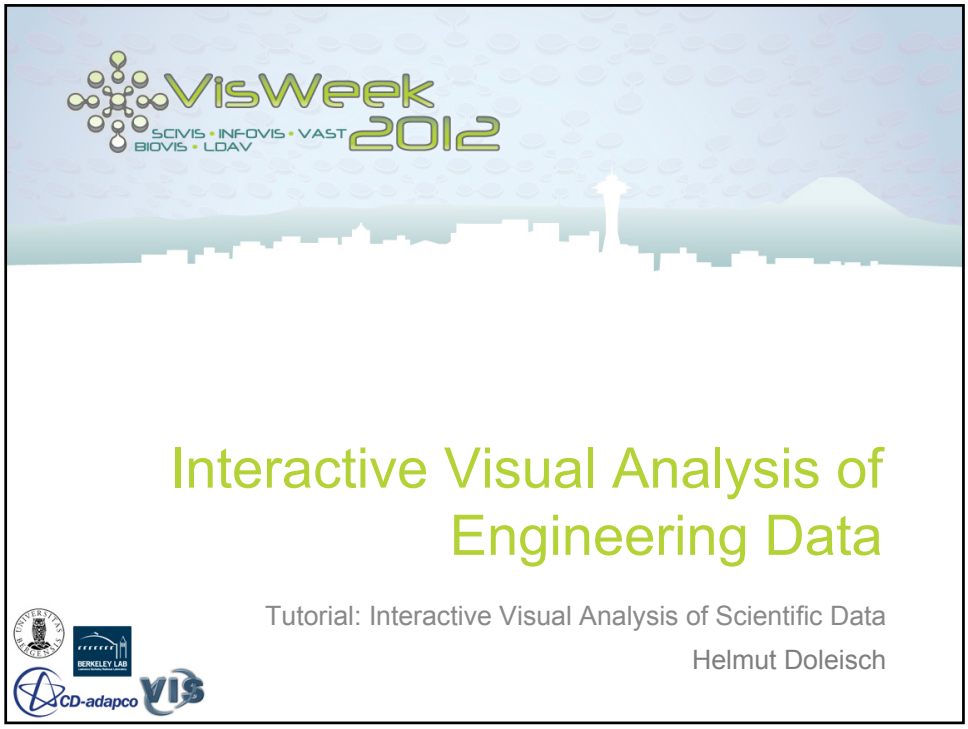


Interactive Visual Analysis of Engineering Data

Tutorial: Interactive Visual Analysis of Scientific Data

Helmut Doleisch

Outline

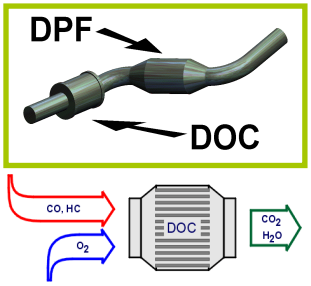
- Motivation
- IVA of a diesel exhaust system
- IVA of a two stroke engine
- Further application examples
- Summary and Conclusions

Motivation

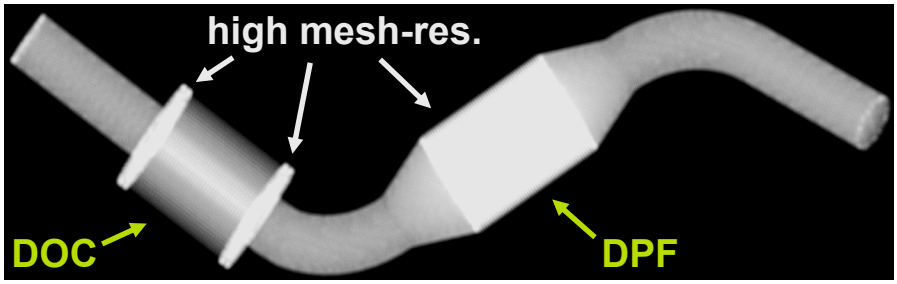
- Challenges with respect to state-of-the-art simulation data
  - Large data
  - Multivariate (scalar, vector, many attributes)
  - Complex 3D geometries
    - Unstructured grids (e.g. arbitrary polyhedra, concave cells, large variety in cell sizes, …)
    - Overlapping, multiple grids (e.g. overset meshes)
  - Time-dependent data
    - Possibly with time-dependent geometry
- All this makes interactive visual analysis complicated
  - But also extremely useful for exploration and analysis of such data

IVA of a Diesel Exhaust System

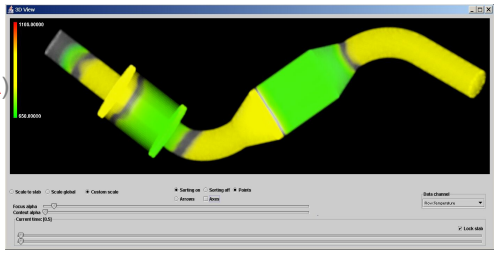
- Diesel Exhaust System
  - Diesel Oxidation Catalyst
  - Diesel Particulate Filter
- DOC: reduce emissions
  DPF: trap soot particles
- Periodic regeneration of DPF (oxidation)
  - should burn soot as much as possible
  - should last as short as possible
- Data: CFD simulation (#: ~¼M, 37 d_i, 20 t_i)



Case: Overview and Exploration



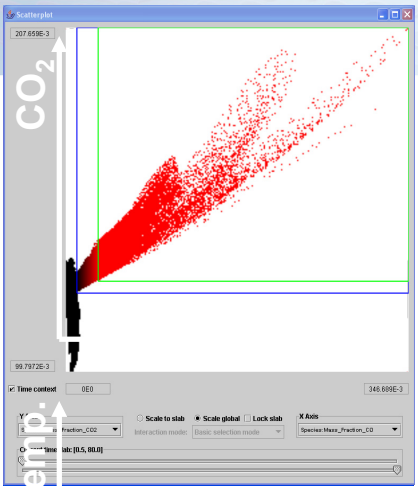
- Three bands of temperature (725°C±Δ, 875°C±Δ, 1025°C±Δ)
- Through 80s of time



IVA of a Diesel Exhaust System

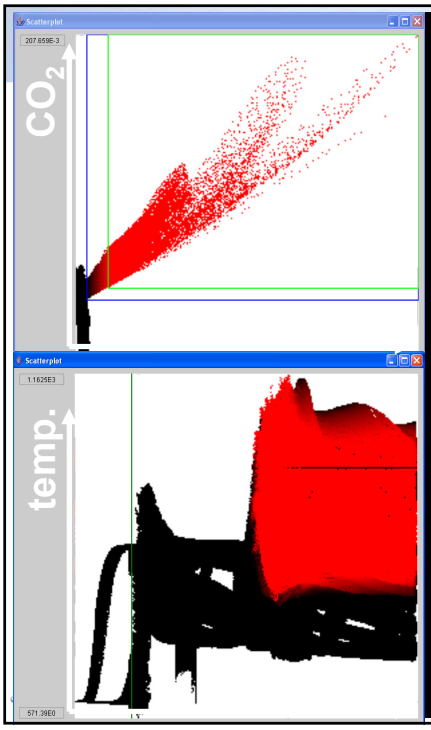
- Carried out as case study with application experts:
- typical application questions include [Doleisch et al. 2004]
  - Does soot oxidize completely (if not, why)?
  - Where/how does soot oxidize (and why)?

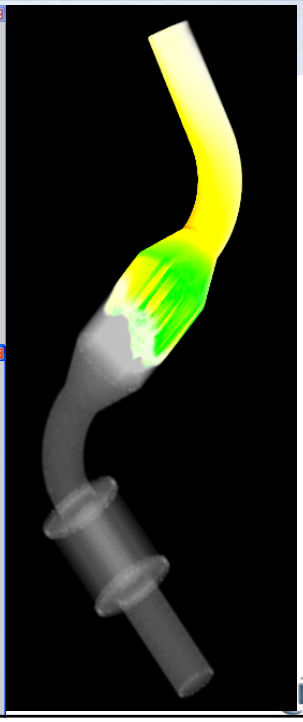
- What do you want to look at / analyze?
  - Oxidation yields CO, CO_2 and happens at high temperatures
  - Gradients d *soot_mass* / d *t* << 0 ⇒ lots of soot is oxidized



Oxidation Analysis

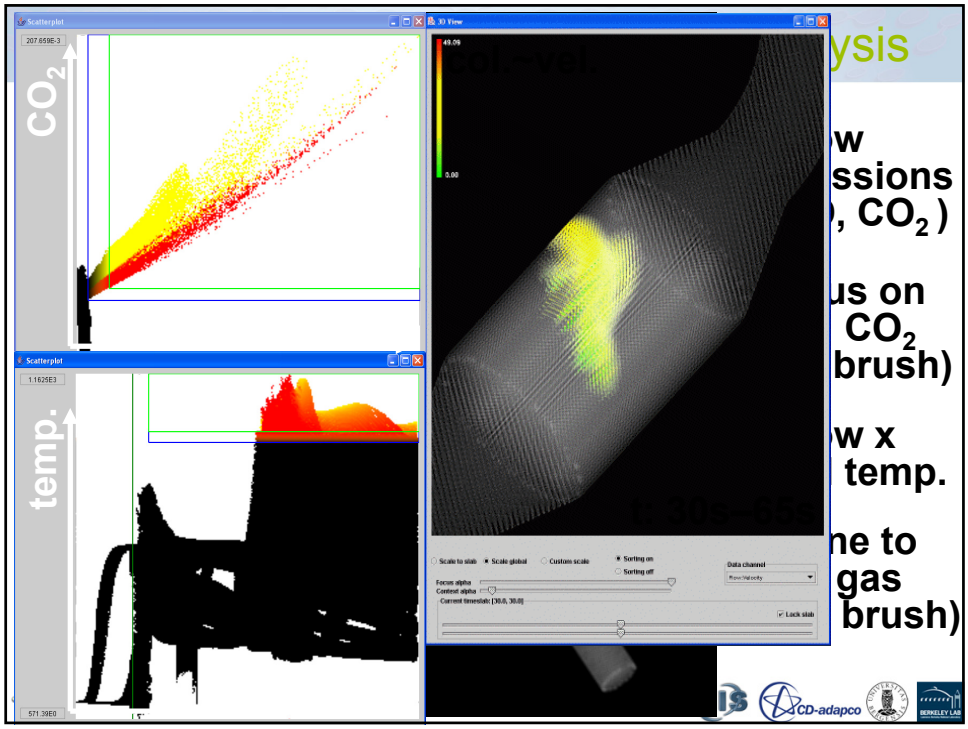
1. show emissions (CO, CO_2)





Analysis

1. show emissions (CO, CO_2)
2. focus on CO, CO_2 (1st brush)
3. show x and temp.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w
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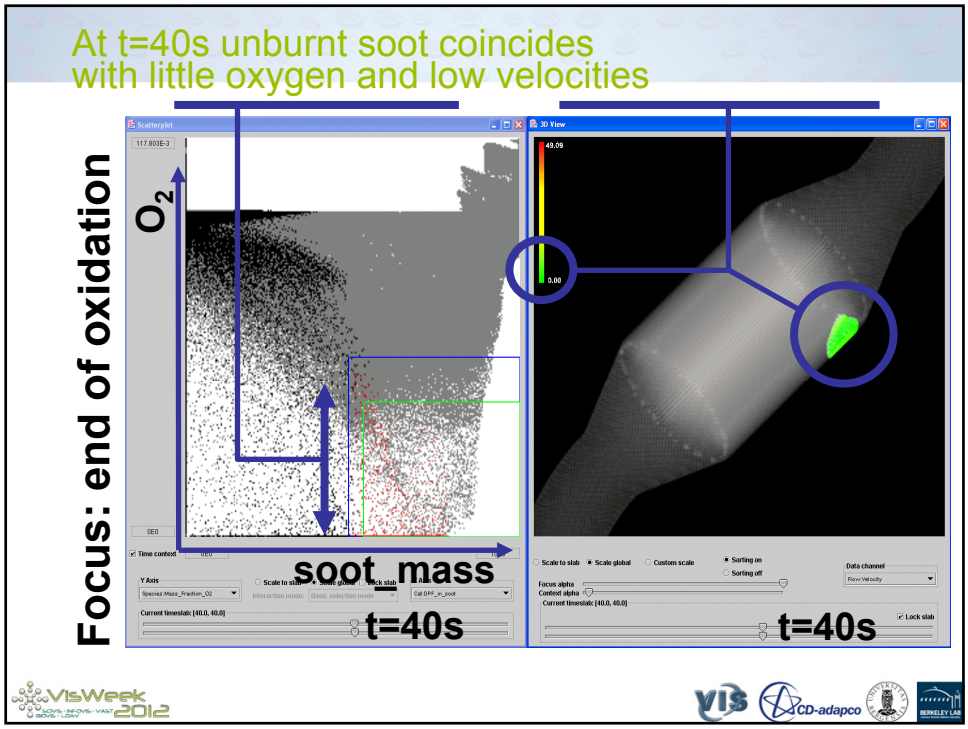
, CO_2)
us on
CO_2
brush)
w x
temp.
ne to
gas
brush)
CO_2
temp.


At t=40s unburnt soot coincides
with little oxygen and low velocities
Focus: end of oxidation
O_2
soot_mass
t=40s
t=40s
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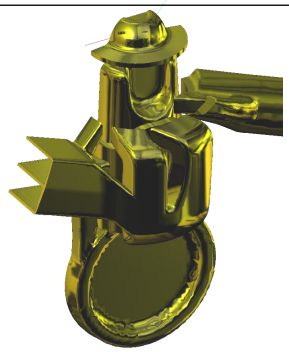
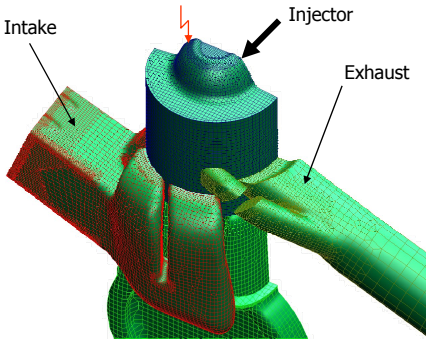
IVA of a High-pressure 2-Stroke Engine

- 3D CFD-Simulation of a 2-Stroke Engine with High Pressure GDI Injection

Single Cylinder, 2-Stroke Engine
500cc, Direct Injected

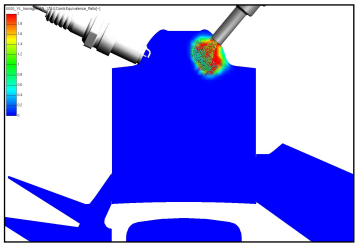




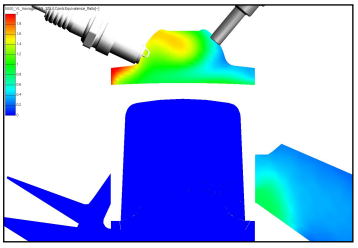
Commonly used Techniques

Standard examination techniques use the following approaches:

- 2-dimensional visualization of the 3-dimensional spatial fluid conditions
  - Several views from different angles
  - Array of views at several time steps
  - Video



Equivalence Ratio at 10°CA ASOI

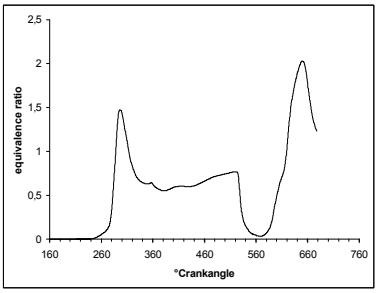


Equivalence Ratio at Time of Ignition

Commonly used Techniques

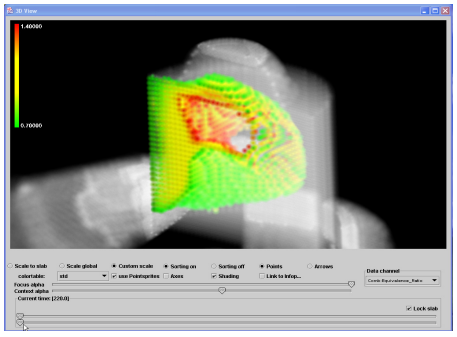
Standard examination techniques use the following approaches:

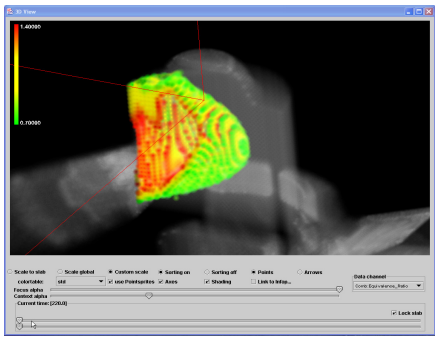
- 2-dimensional visualization of the 3-dimensional spatial fluid conditions
  - Several views from different angles
  - Array of views at several time steps
  - Video
- Display of several variables compared with each other in a spreadsheet, etc.
  - bar chart
  - graphs



Equivalence Ratio during Revolution

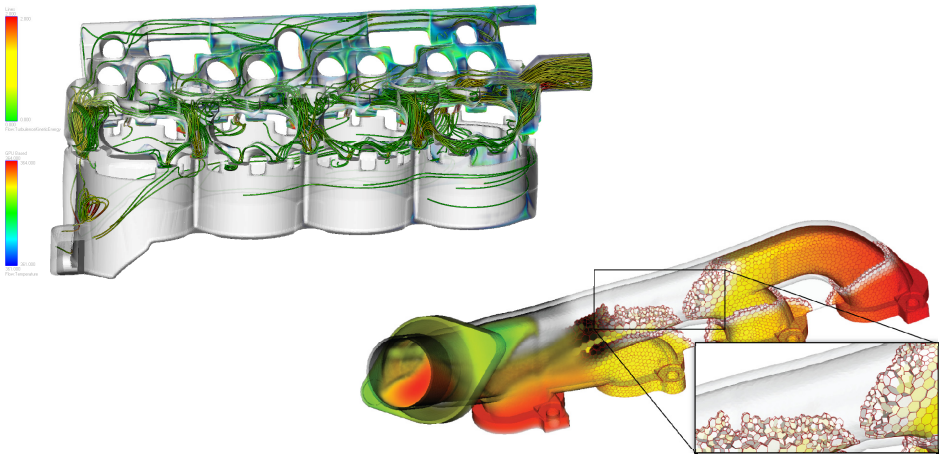
Data Exploration with SimVis



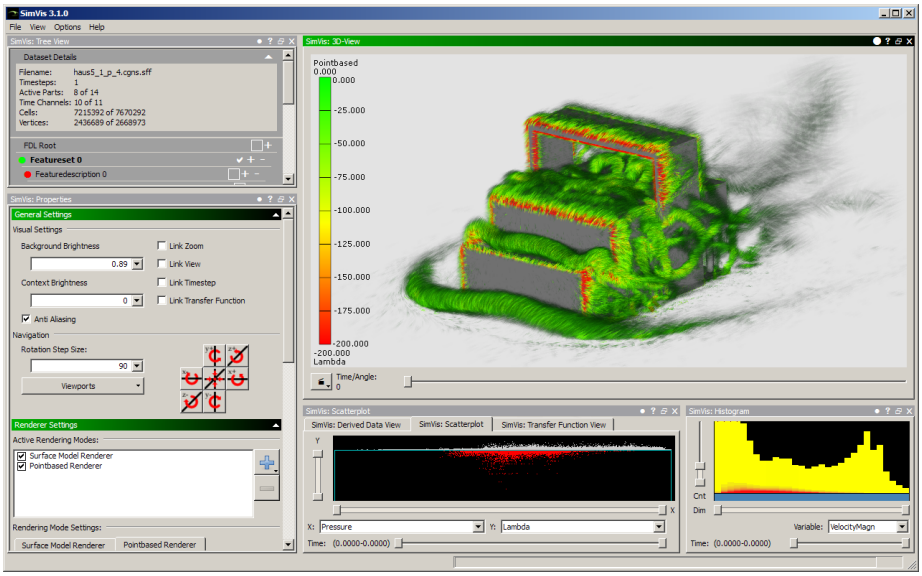


Further Application Examples

- Other automotive applications (water cooling, aerodynamic, climate control, accoustic simulations, etc.)

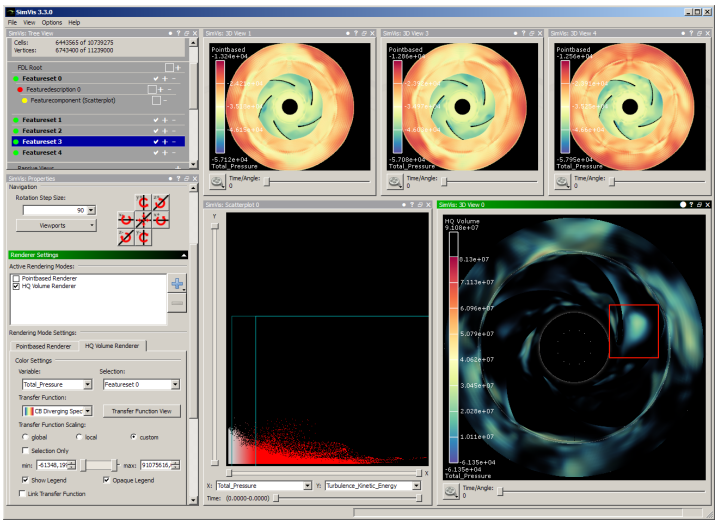


Further Application Examples



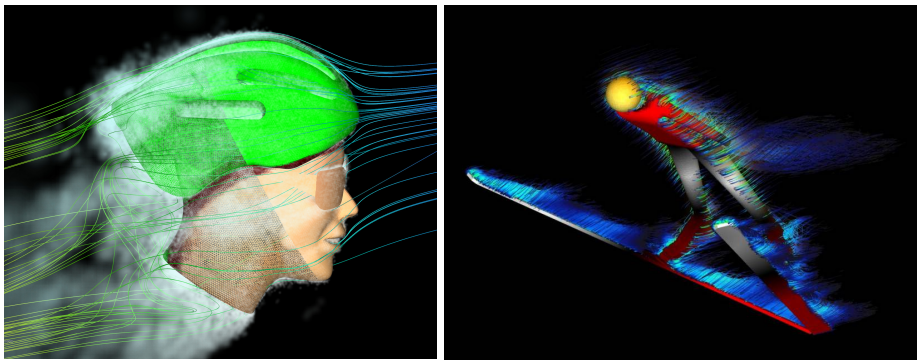
Further Application Examples

- Ventilation systems, pumps, etc.



Further Application Examples

- Aerodynamics in sport and design …



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Further Application Examples

- And many more ….
  - Oil and gas
  - Energy
  - Maritime applications
  - Flight and Aerospace
  - Consumer electronics
  - …
- Not covered here:
  - IVA of scientific data without dedicated spatial characteristics (1D simulations, system simulations, electronic circuits, etc.)

Summary and Conclusions

- Showcases are just examples, methodology is generally applicable in engineering disciplines
- IVA is new to application engineers, you have to educate potential future users
- New powerful tool for in-depth analysis in complex problems
  - Analyze multivariate behavior
  - Find out unexpected behavior
  - Explore complex spatial, temporal and attribution-based correlations
- Visualization community has to be aware of limitations of existing workflow (no full data access on client, limited hardware, complex geometries and data structures, …)