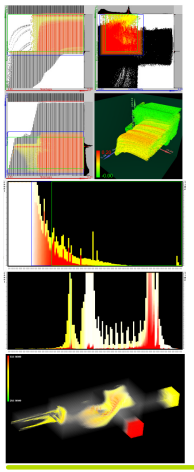


Interactive Feature Extraction

and

Focus+Context Flow Visualization

Helwig Hauser

VRVis Research Center,
in Vienna, Austria

http://www.VRVis.at/

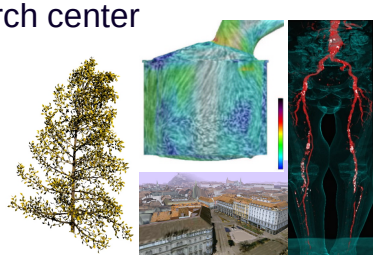
v r vis

Overview

- About VRVis & Helwig Hauser
- Motivation, the basic idea
- An illustrative example
- Technological aspects
- SimVis specials
  (SimVis: VRVis prototype)
- Case from automotive industry
- Summary, pro & contra, etc.

VRVis Research Center

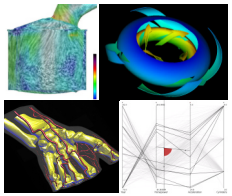
- Non-university research center in Vienna, Austria
- Research in
  - virtual reality (VR…),
  - visualization (…Vis),
  - 3D rendering,
  - 3D reconstruction



- Co-financed projects (industry&funding), ~70 heads, ~45FTE, ~4MEUR turnover
- Operating since 2000, http://www.VRVis.at/

Helwig Hauser

- Visualization researcher since mid-1990s
  - flow visualization (~25 papers)
  - volume visualization (~15 ps.)
  - information visualization (10)
  - etc.



- Initiator of SimVis research @ VRVis (SimVis: focus of this talk)
- Scientific director of VRVis (2003–)

Why Feature-Based FlowViz?

- Flow datasets usually large and complex
  - 10^4–10^6–… cells, 10^0–10^2–… time steps
  - complex grid geometries (unstructured)
  - many data dimensions
- Tough challenge to gain insight
- Feature-based FlowViz = focussing
  - look at what is most interesting
  - concentrate on most important features
  - answer concrete user questions

Flows & Features – Directions

- From numbers to flow features…
- From plain to structured flows…
- From low-level to high-level…
- From syntax to semantics…
- From data to information…
- From local to global…
- Towards tangible flows…

Feature Extraction – Variants

- ✓ Extraction of predefined features
  - vortices, vortex cores
  - shock waves
- ✓ Extraction of flow topology
  - critical points, separatrices
  - boundary switch points/connectors
- ✓ Extraction of flow patterns
  - convergent/divergent flow
  - rotating flow, swirl
- And? ® ***Interactive Feature Extraction!***

(Overview by Post et al.)

Interact. Information Drill-Down

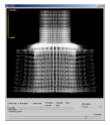
- Ben Shneiderman, 1996: overview first, zoom and filter, then details on demand (visual information seeking mantra)
- Exploration, analysis, then presentation
  - first exploration (no hypothesis)
  - then analysis (guided by hypotheses)
  - eventually presentation (of findings)

Interactive Feature Extraction – *the start*

main direction of work Þ

- SciVis (overview, orientation)
- New View (InfoVis)
- Adjust Projection (InfoVis)
- Brush InfoVis-view
- Linked Visualization
  - Alter Brush
  - Add Brush (® compound brush)
  - Add View (InfoVis)
- (presentation, report, …)

iterative refinement



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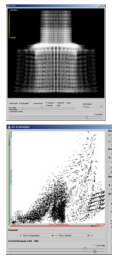
iterative refinement

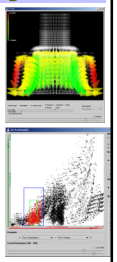


Interactive Feature Extraction – *analysis*

main direction of work Þ

- SciVis (overview, orientation)
- New View (InfoVis)
- Adjust Projection (InfoVis)
- Brush InfoVis-view
- Linked Visualization
  - Alter Brush
  - Add Brush (® compound brush)
  - Add View (InfoVis)
- (presentation, report, …)

iterative refinement



Interactive Feature Extraction – *analysis*

main direction of work Þ

- SciVis (overview, orientation)
- New View (InfoVis)
- Adjust Projection (InfoVis)
- Brush InfoVis-view
- Linked Visualization
  - Alter Brush
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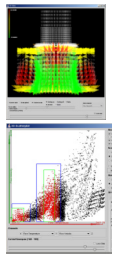
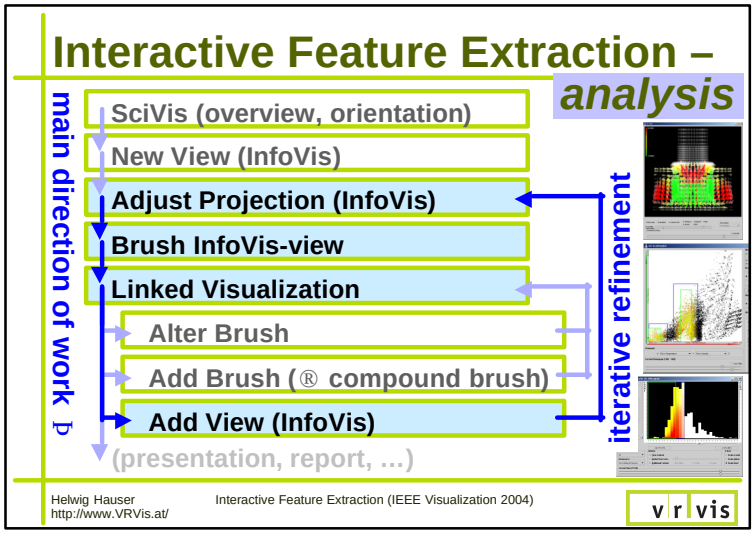
- (presentation, report, …)

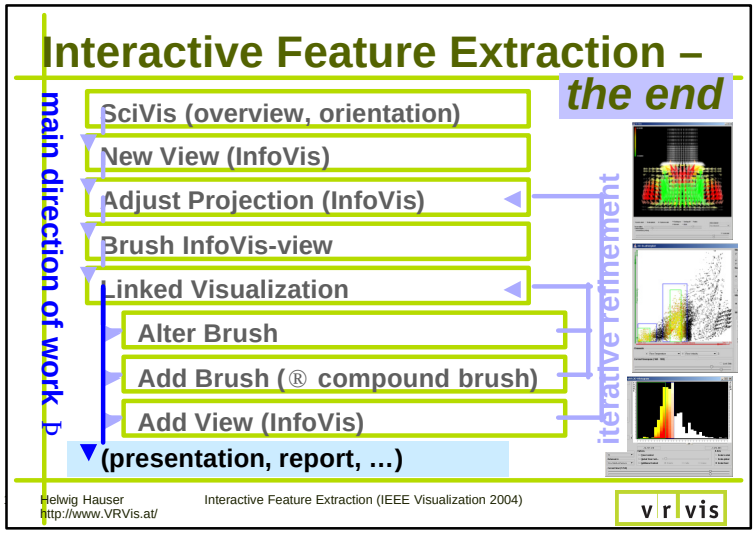
iterative refinement



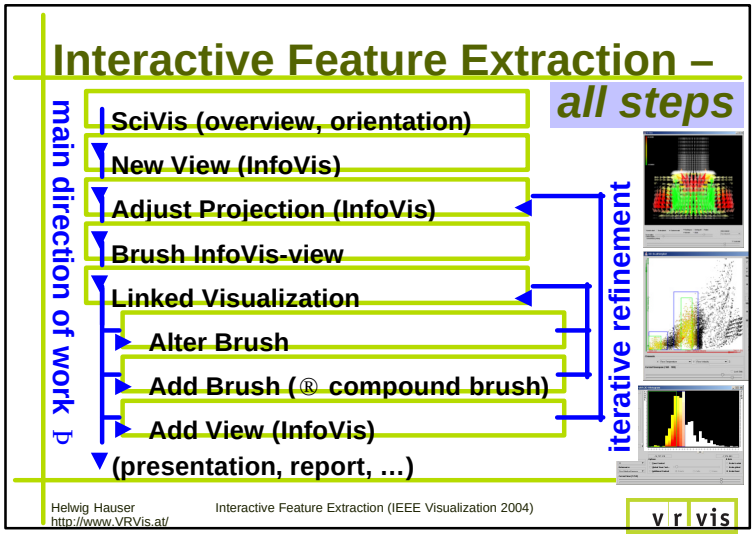
Interactive Feature Extraction – *analysis*



Interactive Feature Extraction – *the end*

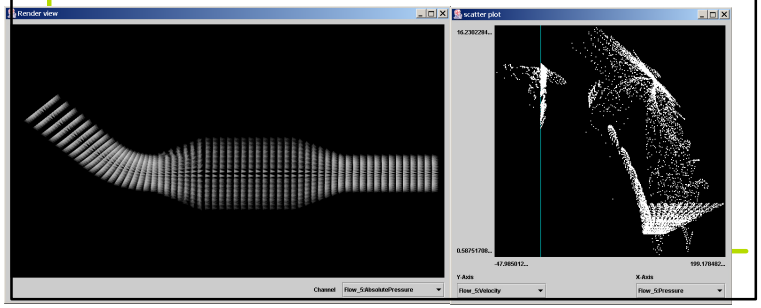


Interactive Feature Extraction – *all steps*



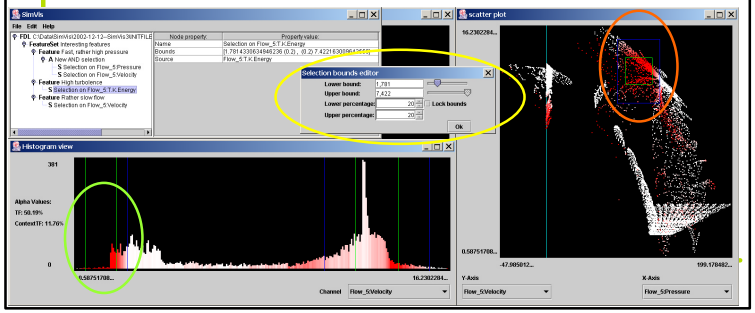
Visualization Example (1)

- Getting started (first overview):
  - SciVis: spatial orientation
  - InfoVis: attribute space



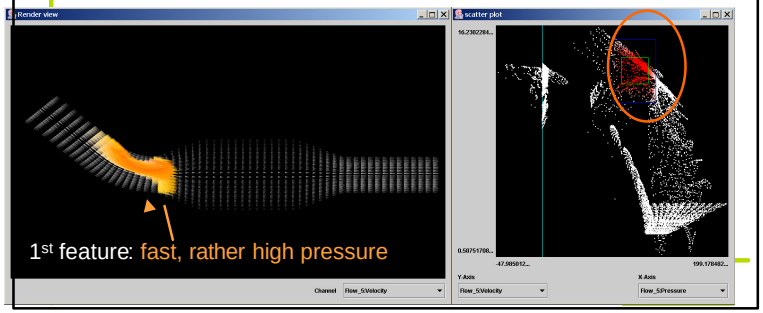
Visualization Example (2)

- Next: feature characterization (drill into)
  - interactive brushing in InfoVis views
  - also numerical specification



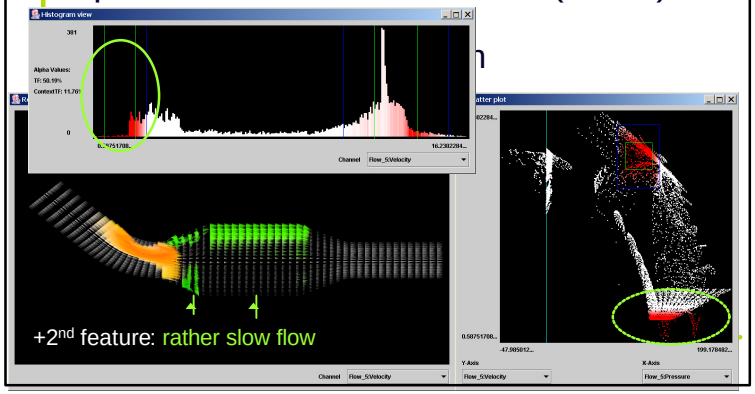
Visualization Example (3a)

- In parallel: linked visualization (relate)
  - 3D view: feature location
  - InfoVis: nDim investigation



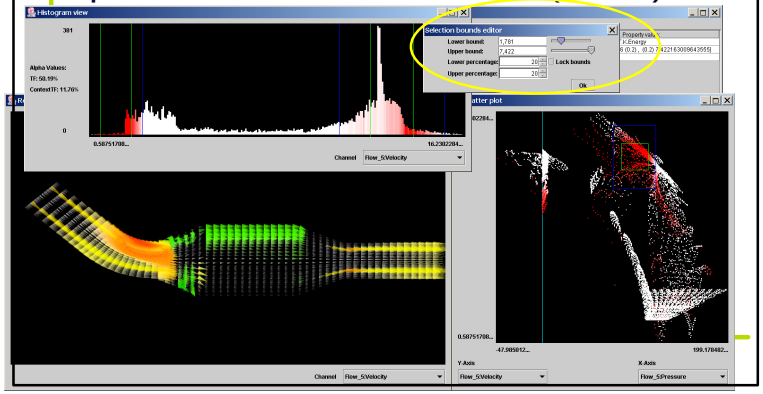
Visualization Example (3b)

- In parallel: linked visualization (relate)



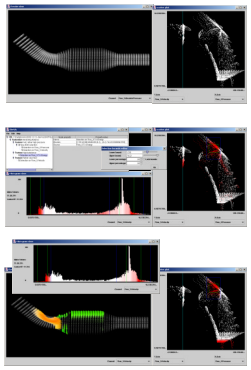
Visualization Example (3c)

- In parallel: linked visualization (relate)



Summary of Analysis Steps

- Overview
  - SciVis: spatial orientation
  - InfoVis: attribute space
- Feature characterization
  - interactive brushing
  - numerical specification
- Linked visualization (par.)
  - feature localization
  - n-dimensional analysis



Technological Aspects

- Visualization with multiple views
- Linking and brushing
- Focus+context visualization
- Special emphasis on interaction, combination of InfoVis & SciVis

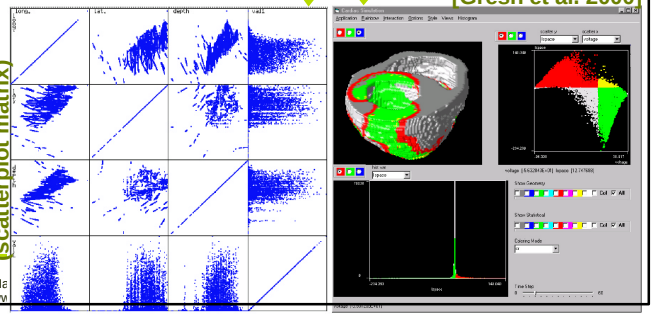
Visualization – Multiple Views

- Show the same data in multiple views:
  - views of different kind
  - different projections

[Baldonado et al. 2000; Ward `94]

(scatterplot matrix)

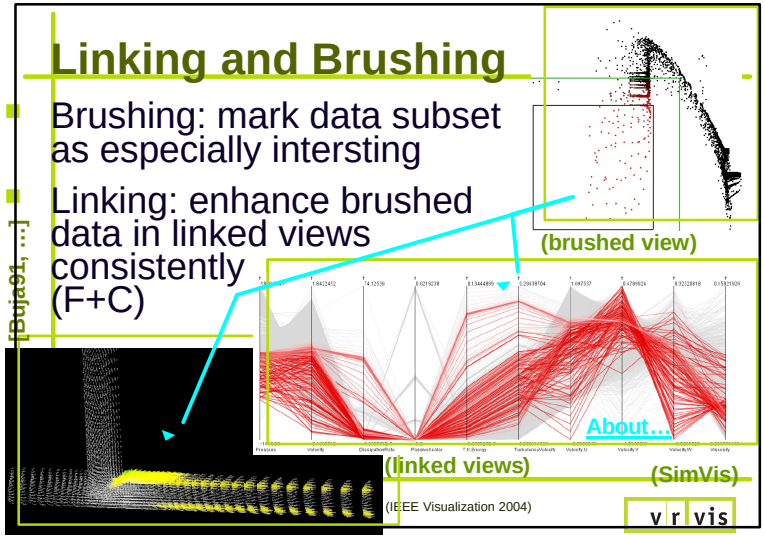
[Gresh et al. 2000]

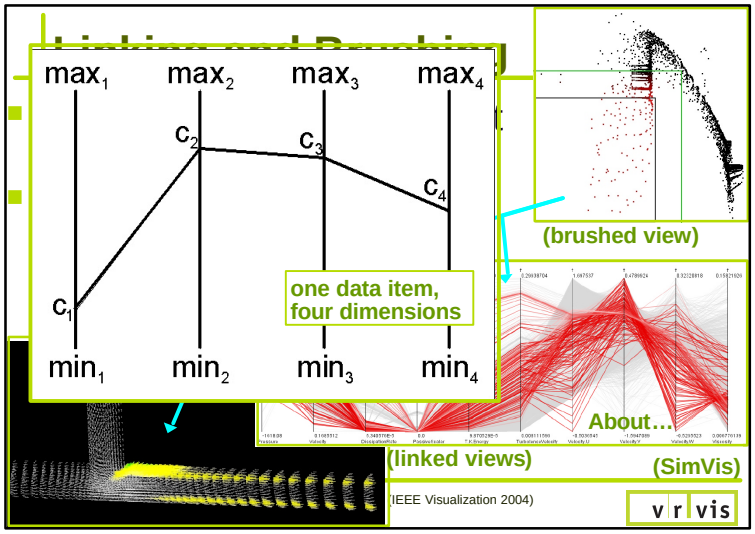


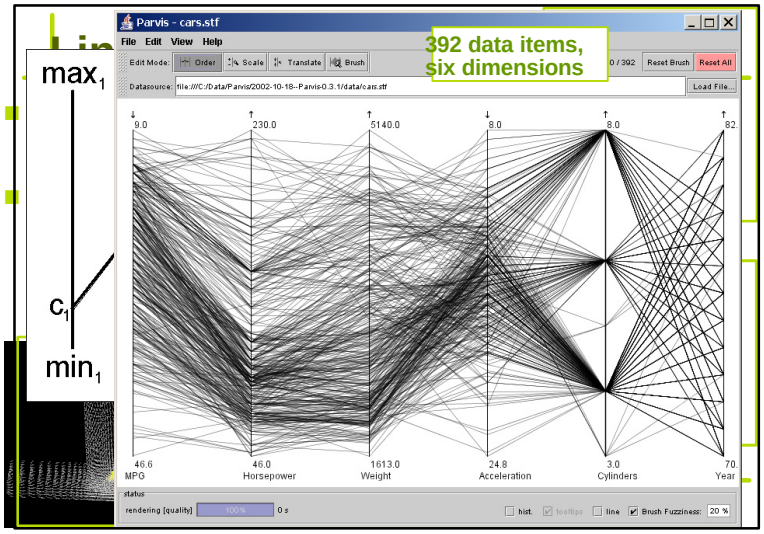
Linking and Brushing

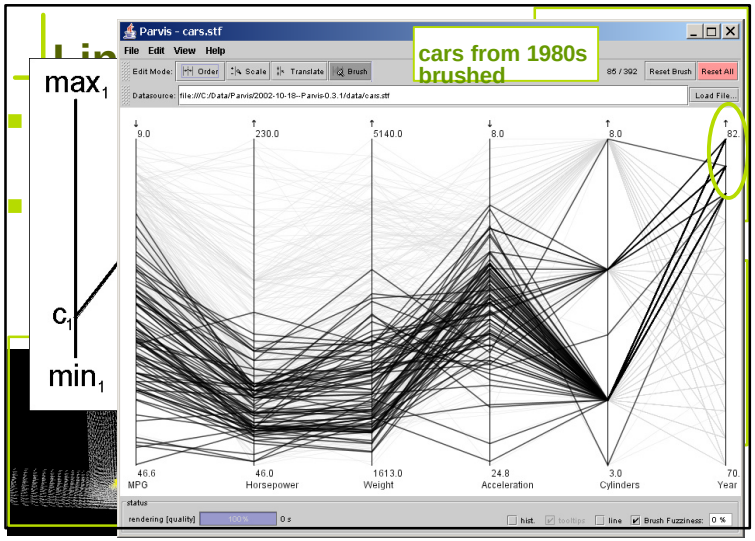
- Brushing: mark data subset as especially intersting
- Linking: enhance brushed data in linked views consistently (F+C)

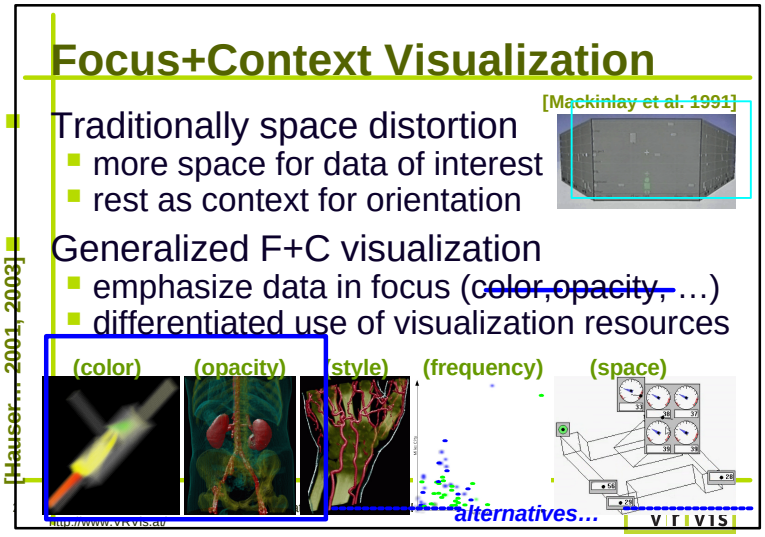
[Buja91, ...]




max1
max2
max3
max4
c2
c3
c4
c1
min1
min2
min3
min4
one data item,
four dimensions
(brushed view)
About…
(linked views)
(SimVis)
(IEEE Visualization 2004)
v r vis

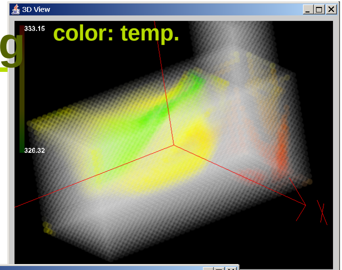

Parvis - cars.stf
File Edit View Help
392 data items,
six dimensions
max1
c1
min1
9.0
230.0
5140.0
8.0
8.0
82
46.6
MPG
46.0
Horsepower
1613.0
Weight
24.8
Acceleration
3.0
Cylinders
70
Year

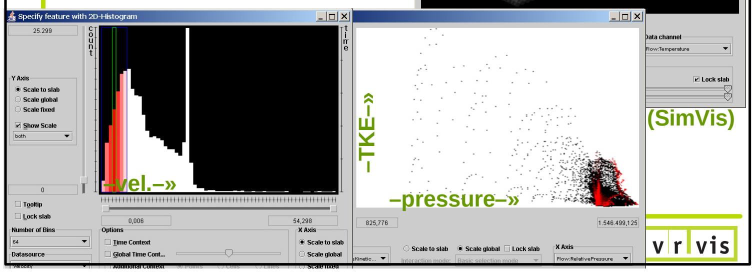

Parvis - cars.stf
File Edit View Help
cars from 1980s
brushed
max1
c1
min1
9.0
230.0
5140.0
8.0
8.0
82
46.6
MPG
46.0
Horsepower
1613.0
Weight
24.8
Acceleration
3.0
Cylinders
70
Year


Focus+Context Visualization
[Mackinlay et al. 1991]
Traditionally space distortion
more space for data of interest
rest as context for orientation
Generalized F+C visualization
emphasize data in focus (color,opacity,…)
differentiated use of visualization resources
[Hauser… 2001, 2003]
(color)
(opacity)
(style)
(frequency)
(space)
alternatives…
v r vis

Interact. Brushing

- Move/alter/extend brush interactively
- Update linked F+C views in real-time





Interact. Brushing

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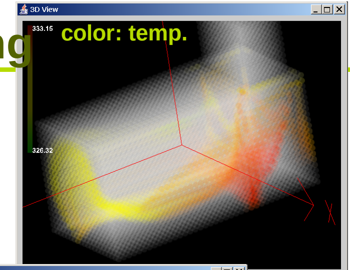
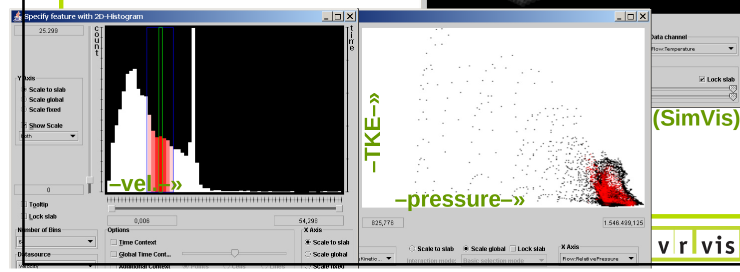
- Update linked F+C views in real-time





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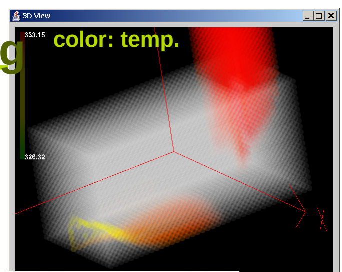
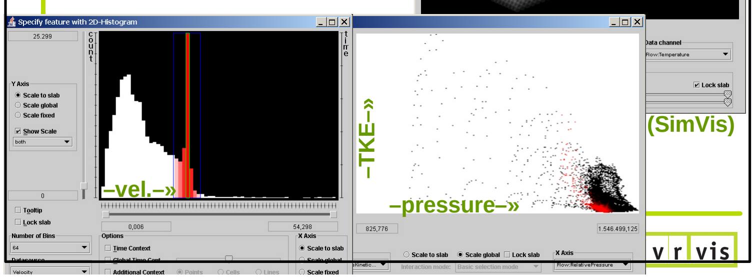
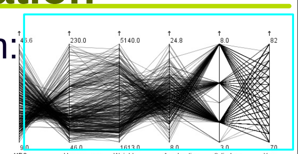
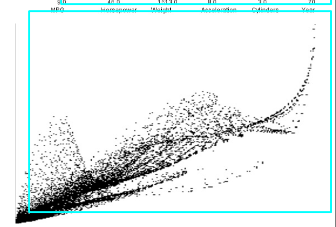




Interactive Visualization

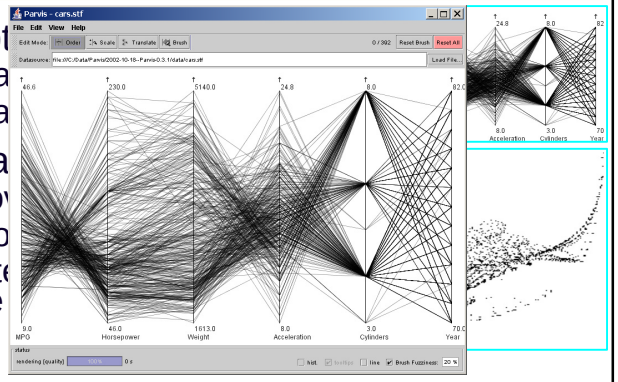
- Adapting the visualization:
  - changing the projection
  - changing the view type
- Interactive focussing
  - moving the focus
  - zooming
  - extending/adapting the focus





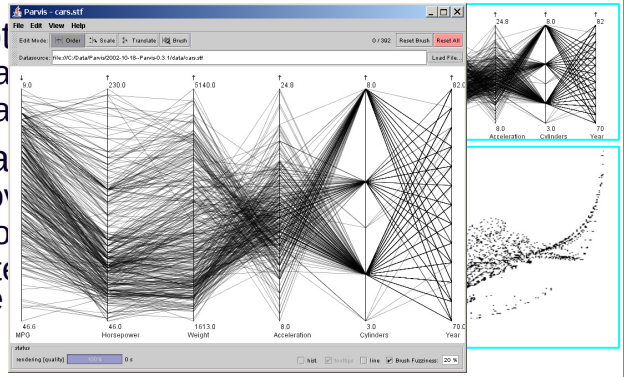
Interactive Visualization

- Adapt
  - cha
  - cha
- Intera
  - mo
  - zoo
  - exte the



Interactive Visualization

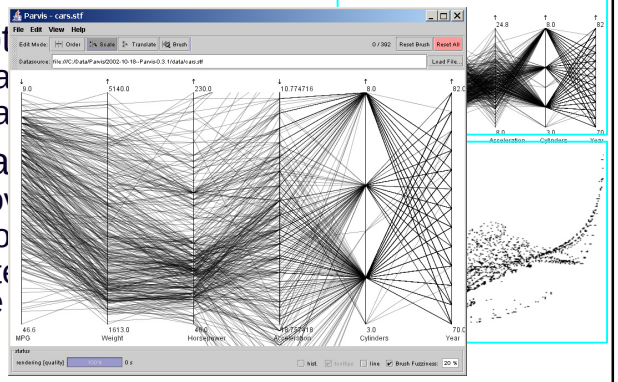
- Adapt
  - cha
  - cha
- Intera
  - mo
  - zoo
  - exte the



Helwig Hauser
http://www.VRVis.at/
Interactive Feature Extraction (IEEE Visualization 2004)
v r vis

Interactive Visualization

- Adapt
  - cha
  - cha
- Intera
  - mo
  - zoo
  - exte the



Helwig Hauser
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Interactive Feature Extraction (IEEE Visualization 2004)
v r vis

Interactive Visualization

- Adap
  - ch
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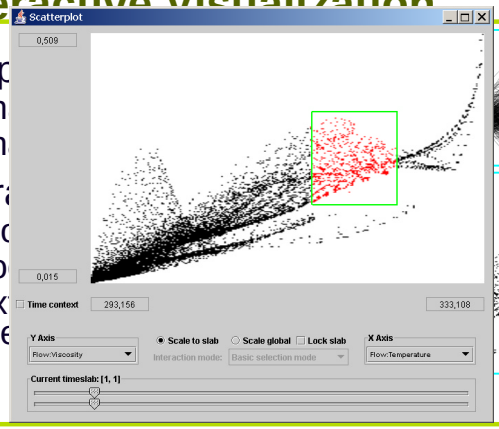

Helwig Hauser
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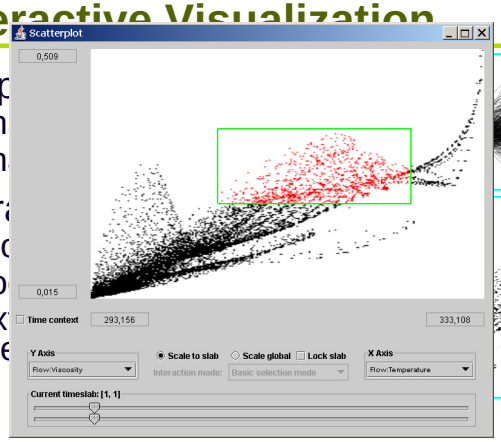
Interactive Feature Extraction (IEEE Visualization 2004)
v r vis

Interactive Visualization

- Adap
  - ch
  - ch
- Intera
  - mo
  - zo
  - ex
    the



Interactive Visualization

- Adap
  - ch
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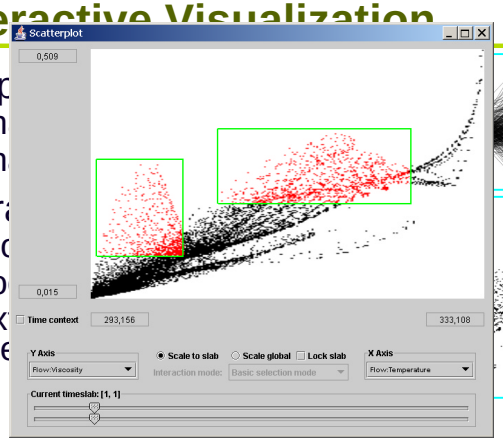
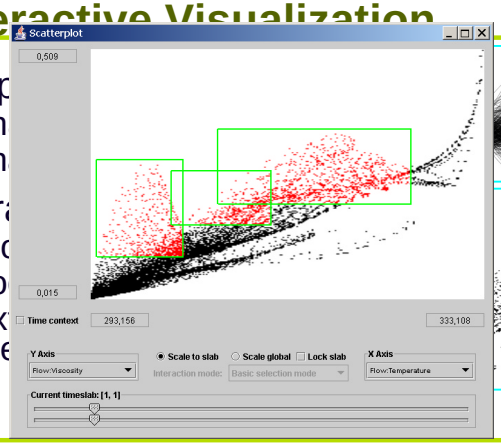
  - ex
    the



Interactive Visualization

- Adap
  - ch
  - ch
- Intera
  - mo
  - zo
  - ex
    the



SimVis Specials

SimVis: VRVis prototype

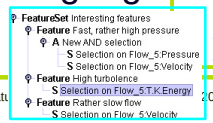
- Feature definition language
- Fuzzy classification (degrees of interest)
- Advanced brushing mechanisms
- Attribute derivation
- Extended views

Feature Definition Language

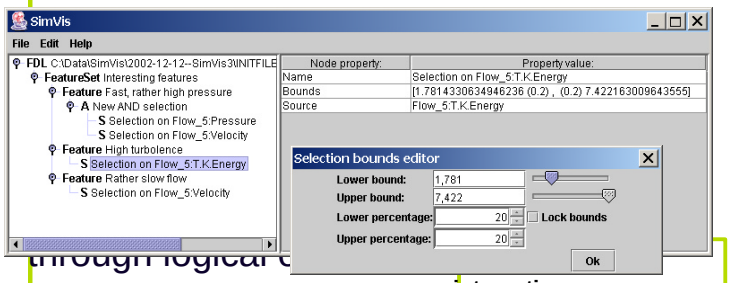
- User interest is represented explicitly as degree of interest (DOI)
- DOI: additional data dimensions
- Brushing results in DOI attribution
- Feature characterization: tree structure through logical operators
- Follows natural language
- In/out: XML

[Doleisch et al. 2003]

Example:
interesting are ...
... flow regions where
pressure is low
AND temp. is high
AND velocity is high



Feature Definition Language



- Follows natural language
- In/out: XML

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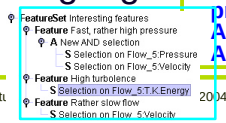
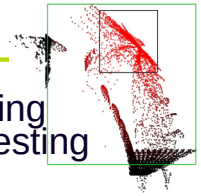
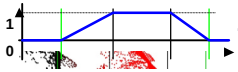


Fuzzy Classification

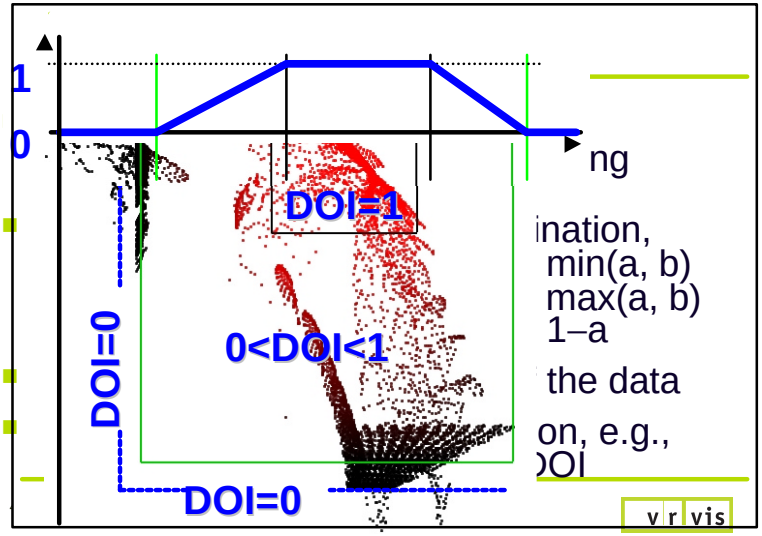


- DOI ∈ [0,1] – 0 … not interesting
  1 … 100% interesting



- Requires fuzzy logic for combination, we use
  $c = a \wedge b \Leftrightarrow c = \min(a, b)$
  $c = a \vee b \Leftrightarrow c = \max(a, b)$
  $c = \neg a \Leftrightarrow c = 1-a$
- Matches the smooth nature of the data
- Goes well with F+C visualization, e.g., opacity varies gradually with DOI

[Doleisch & Hauser 2002]



ng

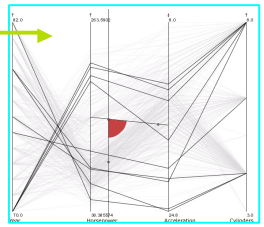
ination,
min(a, b)
max(a, b)
1–a

the data

on, e.g.,
DOI

Advanced Brushing

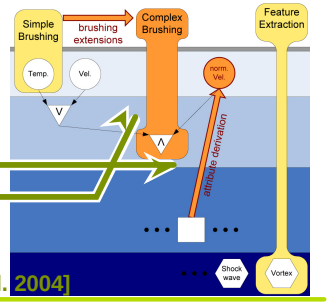
- Smooth brushing
  to acquire gradual DOI-values
- Angular brushing
  in parallel coordinates
  to brush relations
- Compound brushes
  to build up a DOI tree
  (cf. Martin… `95, Wills `96, Chen 2003)
- Alternative brush shapes
  to ease interactive feature access



[Hauser et al. 2002]

Attribute Derivation

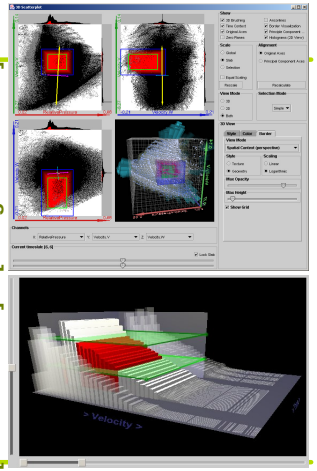
- Comprehensible ways to derive synthetic data dimensions from original data
  - data smoothing
  - derivative information
  - similarity information
  - local minima/maxima
- Attribute derivation
  + advanced brushing
  = access to complex features



[Doleisch et al. 2004]

Extended Views

- InfoVis for large data
- 3D (3D scatterplot, histogram in 3D) with improvements wrt. perception
- Time esp. treated
- Advanced F+C vis. (four-level F+C vis.)

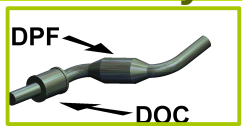


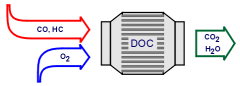
[Piringer et al. 2004]

[Kosara… 2004]

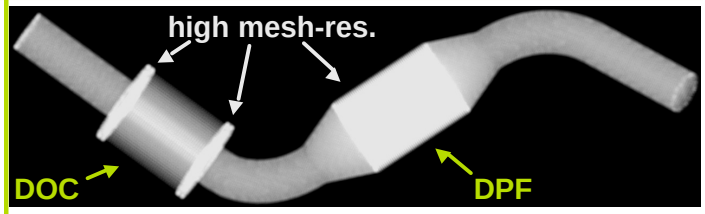
Case from Automotive Industry

- 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)

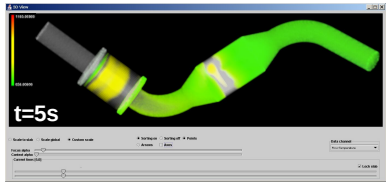




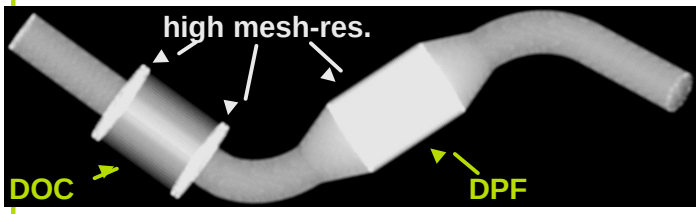
Case: Overview and Exploration



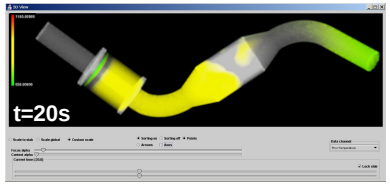
- Three bands of temperature (725°C±Δ, 875°C±Δ, 1025°C±Δ)
- Through 80s of time



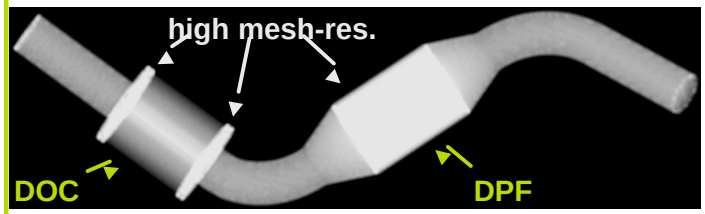
Case: Overview and Exploration



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



Case: Overview and Exploration



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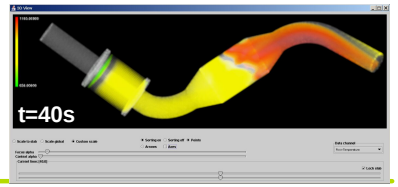
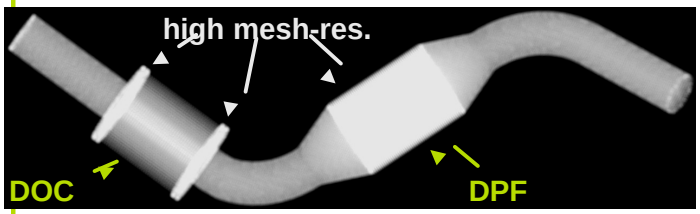
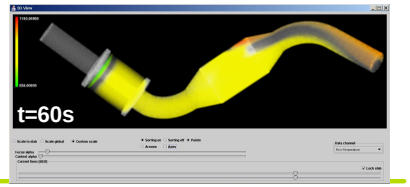
- Through 80s of time



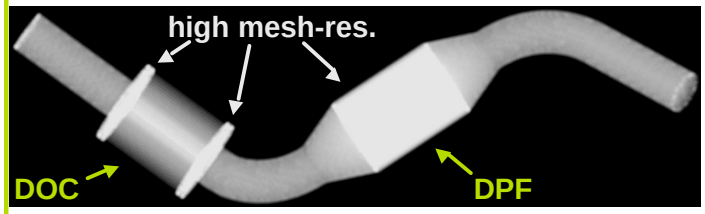
Case: Overview and Exploration



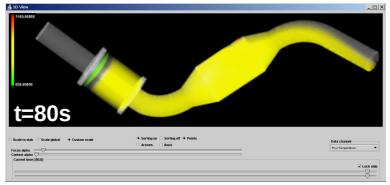
- Three bands of temperature (725°C±Δ, 875°C±Δ, 1025°C±Δ)
- Through 80s of time



Case: Overview and Exploration



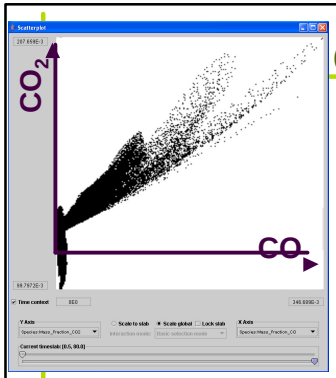
- Three bands of temperature (725°C±Δ, 875°C±Δ, 1025°C±Δ)
- Through 80s of time



Case: Diesel Exhaust System

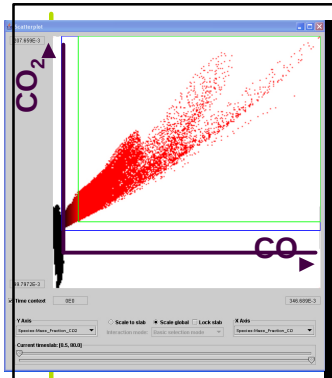
- Case study: three application questions [Doleisch et al. 2004]
  - Does soot oxidize completely (if not, why)?
  - Where/how does soot oxidize (and why)?
  - How about thermal stress in the PDF? *see paper…*
- Oxidation yields CO, CO_2 and happens at high temperatures
- Gradients $d\,soot\_mass / d\,t << 0$
  $\Rightarrow$ lots of soot is oxidized

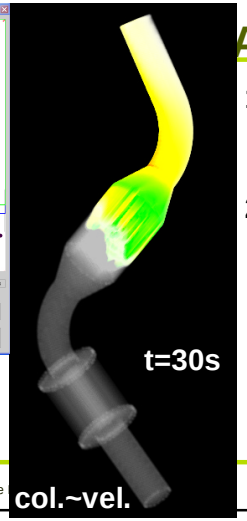
Oxidation Analysis



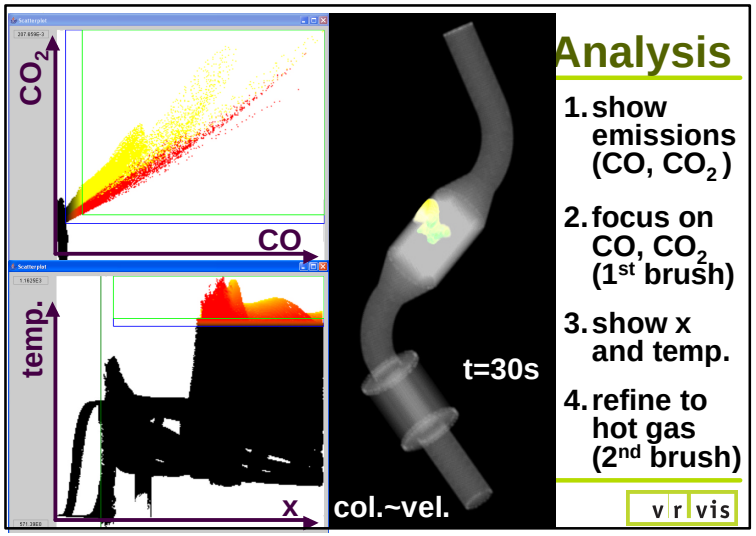
1. show emissions (CO, CO_2)

Analysis





1. show emissions (CO, CO_2)
2. focus on CO, CO_2 (1st brush)



Analysis

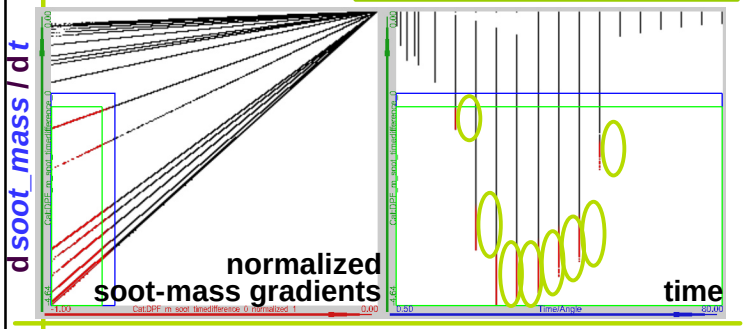
1. show emissions (CO, CO_2)
2. focus on CO, CO_2 (1st brush)
3. show x and temp.
4. refine to hot gas (2nd brush)

v r vis

Soot Burning

Focus: soot is burnt a

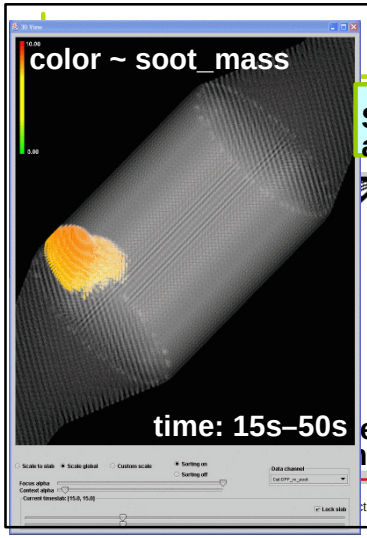
Soot is burnt asymmetrically



Helwig Hauser
http://www.VRVis.at/

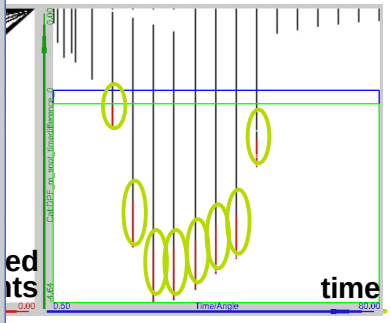
Interactive Feature Extraction (IEEE Visualization 2004)

v r vis



Soot Burning

Soot is burnt asymmetrically



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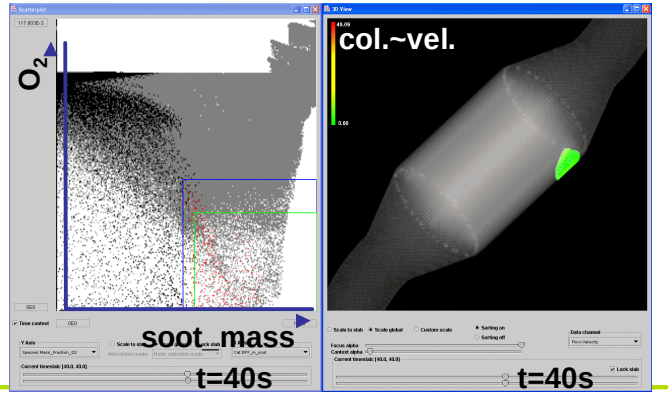
tion (IEEE Visualization 2004)

v r vis

At t=40s unburnt soot coincides with little oxygen and low velocities

Focus: end of oxidation



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v r vis

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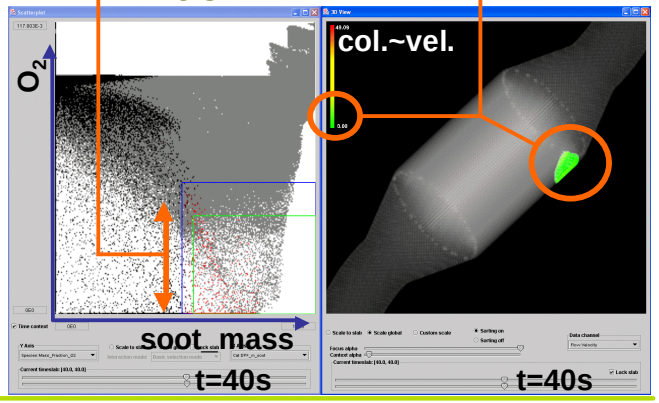

Interactive Feature Extraction

- Enable interactive, visual flow analysis
- Use the “language” of engineers
- Make feature extraction comprehensible
- Enable information drill-down
- Iterative feature specification

Interactive Feature Extraction

Pro

+ 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 flow sim. data)
+ comprehensible (analysis in the terms of the engineers)

Contra

– potentially computationally expensive (context remains in memory, frequent DOI computations)
– not for all kinds of features (limited feature complexity)
– suboptimal for presentation (InfoVis is abstract, requires learning)

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- Kplus – for funding this research
- Helmut Doleisch, Martin Gasser
- Markus Hadwiger, Robert Kosara, Michael Mayer, Harald Piringer, and many others

- http://www.VRVis.at/

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