Interactive Visual Analysis of Complex Data: Families of Surfaces

Krešimir Matković
Vienna University of Technology, VRVis Research Center, Vienna
Overview

Complex data: families of surfaces

- Meteorology
- Engineering
- Car racing

Model view integration

InfoVis wrap-up
Overview

Complex data: families of surfaces

- Meteorology
- Engineering
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Model view integration

InfoVis wrap-up
Meteorology model 1

Climate research at the PIK institute

# Meteorology model 2

<table>
<thead>
<tr>
<th>Time step</th>
<th>Diff_h</th>
<th>Diff_v</th>
<th>output 1</th>
<th>output2</th>
<th>…</th>
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</table>
Multiple runs

Multiple runs:
- two diffusivity parameters
  - 10 steps each - 100 runs
  - 500 time steps (1 step = 1 year) – per run

35 different results aggregated from the more detailed raw simulation data (temperature, ...)

Common way of storing the data:
- multiply previous table 100 times, 50 000 rows now
- 3 independent variables now timestep, diffh, diffv

<table>
<thead>
<tr>
<th>Time</th>
<th>Diff_h</th>
<th>Diff_v</th>
<th>output1</th>
<th>output2</th>
<th>…</th>
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<td>dv10</td>
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</tr>
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</table>
Multiple runs - exploration

Mappings as dimensions - curves

Mapping as a dimension [Konyha et al. 2006]:
- group results for one run
- outputs are not scalar any more
- but functions of time
- 100 rows now

<table>
<thead>
<tr>
<th>Run</th>
<th>Diff_h</th>
<th>Diff_v</th>
<th>Output1(t)</th>
<th>Output2(t)</th>
<th>…</th>
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</thead>
<tbody>
<tr>
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<td>dh1</td>
<td>dv1</td>
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<td>dh10</td>
<td>dv10</td>
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<td></td>
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</table>
Mappings as dimensions - surfaces

Curves – we are interested about output as f(time)

What if we are interested in outputs as f(x,y)?

Group outputs from all runs in a “surface”
  - e.g. temperature = f (diffh, diffv)

500 rows now, one for each time step

Offers new possibilities for analysis

<table>
<thead>
<tr>
<th>Timestep</th>
<th>Output1(diffh, diffv)</th>
<th>Output2(diffh, diffv)</th>
<th>…</th>
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<td></td>
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<td></td>
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<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
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</table>
Visualization of family of surfaces

Family of curves
- curve view shows them all
- works great

Family of surfaces
- show them all!
- it does not work!

We can show single surface but

Cannot show whole family at once

If we cannot see it we will grasp it thorough interaction

Analysis of family of surfaces

Look at the data at different levels

Three levels of detail:

- analysis through single scalar aggregates (overview)
  - reduction by 2 dimensions
- analysis through aggregated profiles (drill down)
  - reduction by 1 dimensions
- analysis through surfaces (details on demand)
  - no dimension reduction but selective visualization

Single Scalar Aggregates

Overview, statistics

- first step
- reduce su
- use comn
- get the fi
- explore tl
- family – r

Aggregated Profiles

General
- reduce dimensionality if you cannot show it

Profiles
- level 2
- reduction operators
- project the surface to the plane
- min, max, median, average, etc.

Analysis
- advanced analysis
- very complex, challenging, and powerful

Krešimir Matković
InfoVis, TU Wien, 26. 04. 2012
Surfaces

Overview

Complex data: families of surfaces

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- Car racing

Model view integration

InfoVis wrap-up
EHD bearing

Important part in IC engine

Durability, performance, wear, noise

Two step analysis

225 simulation runs – 4 to 5 days on a standard PC

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Table 2. Output values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Name</th>
<th>Unit</th>
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<tr>
<td>Groove Length</td>
<td>CLEA</td>
<td>mm</td>
</tr>
<tr>
<td>Hydrodynamic pressure</td>
<td>PRES</td>
<td>MPa</td>
</tr>
<tr>
<td>Asperity contact pressure</td>
<td>PRSA</td>
<td>MPa</td>
</tr>
<tr>
<td>Total pressure</td>
<td>PTOT</td>
<td>MPa</td>
</tr>
<tr>
<td>Fill ratio</td>
<td>PILL</td>
<td></td>
</tr>
<tr>
<td>Hydrodynamic shear stress</td>
<td>TAHS</td>
<td>MPa</td>
</tr>
<tr>
<td>Asperity contact shear stress</td>
<td>TAAS</td>
<td>MPa</td>
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InfoVis, TU Wien, 2
Analysis snapshot 1

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InfoVis, TU Wien, 26. 04. 2012
Analysis snapshot 2

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InfoVis, TU Wien, 26. 04. 2012
Overview

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InfoVis wrap-up
Race Car Setup

The Open Car Race Simulator - TORCS

Parameters varied

- Wing Angle: 8–18 degrees (six steps)
- Brake Ratio: 0.41–0.50 (five steps)
- Max. Brake Pressure: 6,500–19,000 (six steps)
- Gear Sets: Six different gearbox sets (six steps)
- Front Spring: 1,000–2,000 (three steps)
- Rear Spring: 1,000–2,000 (three steps)

Telemetry data saved

## Single run

<table>
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<tr>
<th>Lap</th>
<th>Sector</th>
<th>Wing Angle</th>
<th>Brake Ratio</th>
<th>...</th>
<th>Speed</th>
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<td>23</td>
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<td>0.41</td>
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</table>

Krešimir Matković  
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Multiple runs

Multiple runs:
- >9000 variations of car parameters
- 20 laps per simulation, 23 sectors

Telemetry data stored

Common way of storing the data:
- multiply previous table 9000 times
- 7 independent variables now lap, sector, car parameters
<table>
<thead>
<tr>
<th>Lap</th>
<th>Sector</th>
<th>Wing Angle</th>
<th>Break Ratio</th>
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<td>23</td>
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</tbody>
</table>
Mappings as dimensions - surfaces

Group outputs from all runs in a “surface”
  ▪ e.g. speed = f (lap, sector)

9000 rows now, one for each simulation run

Offers new possibilities for analysis

<table>
<thead>
<tr>
<th>Run</th>
<th>Wing Angle</th>
<th>Speed(lap,sector)</th>
<th>…</th>
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</tbody>
</table>
Analysis of family of surfaces

Analysis of family of surfaces

5/4/2012

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Analysis of family of surfaces

Family of surfaces - conclusion

- Projections along x
- Projections along y

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Overview

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Model view integration

InfoVis wrap-up
Electronic Unit Injector - EUI 1

One injector per cylinder

Used in Diesel engines:
- patent from 1911
- used since 1930s in trucks, locomotives, and ships
- EUI in 1990s
- mostly used in heavy vehicles

Injector design is very important
- emission reduction
- engine efficiency
Model definition:

- standard building blocks are used
- each block has control parameters
- decide which will be varied
- state variables are computed for each block

Multiple simulation runs

AVL Hydsim tool used

1D CFD – fast simulation
- 10 simulation runs per minutes

7 parameters varied – 2880 runs

9 state variables considered in analysis (+ aggregates)
# Data

One record = one run

Various attributes

- scalar - control parameters and scalar aggregates of state parameters
- time series – state variables

<table>
<thead>
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<th>Run</th>
<th>Flow resistance</th>
<th>Closing start</th>
<th>Pressure(t)</th>
<th>Velocity(t)</th>
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Interactive Visual Analysis

Results:
- Use interactive visual analysis to understand the phenomena.
- Use interactive visual analysis to understand the CMV system.
- Many parameters, many views.
- Engineer has to know what is depicted in each view.
The Model View

Engineers are familiar with model view

We want to show results and control parameters in blocks

Control and state variables

Multiple runs!
- various values for control parameters
- various values for state variables - time series

Limited space – three levels

Three Levels

Show control parameters on left, state variables on right

Up to 3 variables (user selects them)

Level one
- histograms used
- if state variables are time series – use aggregates

Level two
- double width and height
- up to six histograms, or fewer larger
- scatter plot also possible (not used in our case)
- aggregates of state variables still used

Level three
- block can not be larger
- floating view with map and time series data

Analysis

Successfully used to analyze and tune EUI for different operation modes

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Analysis – the High Power Mode 1

Square shaped injection curve

High injection pressure
- we want a lot of fuel

Blocks C and D are of main interest

3rd level view configured using model view

3 families of curves

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Analysis – the High Power Mode 2

Select curves with steep rise
- line brush with limited crossing

Refine selection
- only high pressure at the injection start
- stronger fuel penetration – higher power

Refine once more
- subtract too slow rising
- or change limit of the crossing
Analysis – the High Power Mode 3

Second needle opening
- undesired behavior
- can be seen in the curve view
- maybe additional curves are hidden

Use a derived family of function graphs:
- first derivative
- more curves detected
- explore why (see paper)

Analysis – the High Power Mode 4

Select curves with step rise
- line brush with limited crossing

Refine selection
- only high pressure at the injection stage
- Stronger fuel penetration – higher power

Refine once more
- subtract too slow rising
- or change limit of the crossing

Exclude second needle opening

Analysis – the High Power Mode 5

All parameters are always highlighted in the model view

Unlimited Possibilities

Low Consumption mode

Instead of brushing curve view

Use histograms of min and max aggregates of 1st derivative

Further Operation Modes

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Conclusion

Integration of Model view into CMV

- full integration, linked view

Helps users in:

- figuring out the basic behavior based on aggregates
- identifying important elements for a given scenario
- configuring views, select what is displayed by one click
- connecting views to originating models

Very positive feedback from domain experts

- will be included in commercial software in near future
Wrap up

Complex data

Families of curves, surfaces, sets
- Everywhere
- Many possibilities for analysis
- Very hard to do it in a conventional way
- Multiple simulation runs, image collections, car racing, bio-signals, ECG of pregnant sheep!, questionnaires, ...

Ideas

Praktikums – Diplomarbeiten - VAST Challenge!

Info Vis – what we learned?

What is InfoVis

“The use of computer-supported, interactive, visual representations of abstract data to amplify cognition”
Typical Visualization Tasks

Visualization is (can be) good for:

- exploration
  - find the unknown, unexpected
  - hypothesis generation
- analysis
  - confirm or reject hypotheses
  - information drill-down
- presentation
  - communicate/disseminate results
InfoVis Reference Model

![Diagram showing the InfoVis Reference Model with stages involving data, visual form, and human interaction.]

Visual Analytics – What is it?

James Thomas & Kristin A. Cook: NVAC (Natic

"Visual Analytics is the science of analytical reasoning facilitated by interactive visual interfaces"

[Thomas & Cook 2005]
Info Vis – what we learned?

A little bit about colors and perception
Info Vis – what we learned?

TreeMap, table lens, Parallel coordinates, Chernoff faces,...
Info Vis – what we learned?

Some examples from real life

...
Info Vis – what we did not learn?

Software Visualisierung (Andreas Karen)
Visualisierung in der Bioinformatik (Andreas Karen)
Graph Drawing (Andreas Karen)
Text Visualization
Casual InfoVis, Many Eyes
InfoVis and Art
The Top Grossing Film of All Time, 1 x 1  2000

Jason Salavon

The Class of 1990

The Class of 1997

Jason Salavon
# Course Outline

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Event Description</th>
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<td>13:00-17:00</td>
<td>SEM186</td>
<td>Präsentation der Programme. PRÄMIERUNG der besten Programme, StudentInnen, Informationen siehe Modus 2 - Präsentation</td>
</tr>
</tbody>
</table>
Info Vis – what we learned?

Modus 1 (VO):
Oral Exam 75% + Participation 25%
Grades: > 87% 1; > 75% 2; > 62% 3; >= 50% 4; < 50% 5
Oral Exam (VO only modus):
21. 06. 15:00 – 17:00
22. 06. ?
Anfang July?

Thank you!

Special thanks for used materials to H. Hauser, and colleagues from VRVis!