Interactive Visual Analysis of Complex Data 2: Families of Curves, Families of Surfaces, Set Type Data

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Overview

Coordinated Multiple Views

Complex data: families of curves

- Traffic Surveillance
- Engineering
- Bio-Sygnals and ICU Data
  - Heart reinervation
  - IVA of ICU Data
- Animal Paths
- Image Collection
Large Image Collections - Comprehension and Familiarization by Interactive Visual Analysis

Krešimir Matković, D. Gračanin, W. Freiler, J. Banova, and H. Hauser

SmartGraphics 2009
Motivation

Large internet image collections – new phenomena

Already used in research (3D reconstruction, e.g.)

We want to understand collection itself by means of visual analysis

Many potential uses: marketing, sociology, etc.
Data Set

Flicker, more than 3000 images uploaded per minute
>5 billion images as of November 2011!
API available
26 000 + images downloaded
Parameters downloaded & computed
Parameters

External
- 6 image parameters: date taken, number of comments, number of views,...
- 10 user parameters: name, gender, singleness, home town,...

Derived
- More than 60: hue, saturation, lightness, colorfulness, number of frontal faces,...
- Scalar + series (curves)

We use coordinated multiple views for analysis
Derived Parameter - Lightness

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Views for families of curves

Curve view

Segmented curve view
Derived Parameter - Lightness

a. 

b. 

0 1 2 3
4 5 6 7
8 9 10 11
12 13 14 15

c. 

d. 

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Dark Corners Example
Picture View

Parameters are not enough

We cannot imagine an image from parameters
Image as a Brush

Fuzzy spec

Visual ima

Any query

Novel way

Tangible b
A screenshot from analysis
Example 1 – highly saturated M/F
Examples – taken/single
Conclusion – Image Collection

Large image collections offer unlimited opportunities for analysis

New phenomena which will certainly be exploited in the future

Interactive visual analysis can help the user to understand image collection

Image view and image as a brush are necessary when dealing with images
Overview Families of Surfaces

Complex data: families of surfaces

- Meteorology
- Engineering
- Car racing
Overview

Complex data: families of surfaces

- Meteorology
- Engineering
- Car racing

InfoVis wrap-up
Meteorology model 1

Climate research at the PIK institute

Lake Agassiz (North America)
- 4000 years lifespan
- 8000 years ago lake drained due to climate warming

Simulation of cooling of 3.6 K of North Atlantic due to melt water pulse
Meteorology model 1

Climate research at the PIK institute

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Meteorology model 2

Simulation run:
- set two diffusivity parameters
- run simulation for 500 time steps (years)
- 35 different results aggregated from the more detailed raw simulation data (see temperature, land temperature...)

Common way of storing the data:
# 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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diff_h</td>
<td>Diff_w</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>Diff_h</td>
<td>Diff_w</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Diff_h</td>
<td>Diff_w</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td>…</td>
<td>…</td>
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<td>…</td>
<td>…</td>
<td>…</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dh1</td>
<td>dv1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>dh1</td>
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<td>…</td>
<td>…</td>
<td>…</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>500</td>
<td>dh1</td>
<td>dv1</td>
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<td></td>
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</tr>
<tr>
<td>1</td>
<td>dh1</td>
<td>dv2</td>
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<tr>
<td>2</td>
<td>dh1</td>
<td>dv2</td>
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<td></td>
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<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>dh1</td>
<td>dv2</td>
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<tr>
<td>1</td>
<td>dh1</td>
<td>dv3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>dh1</td>
<td>dv3</td>
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<td>…</td>
<td>…</td>
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<tr>
<td>500</td>
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<tr>
<td>500</td>
<td>dh10</td>
<td>dv10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Multiple runs - exploration

Conventional multidimensional data set

CMV used for exploration and analysis
Multiple runs - exploration

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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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dh1</td>
<td>dv1</td>
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<td>2</td>
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<td></td>
<td></td>
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<tr>
<td>3</td>
<td>dh1</td>
<td>dv3</td>
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<tr>
<td>100</td>
<td>dh10</td>
<td>dv10</td>
<td></td>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>
Curve View

Depict all curves at once
Iterative line brush
Domain exerts love it!
Curve View

Depict all curves at once

Iterative line brush

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Curve View Depict all curves at once Iterative line brush Dima 

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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
Mappings as dimensions - surfaces

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

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

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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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</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

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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 surface to minimum, maximum, median,...
- use common views to explore the data
- get the first impression
- explore the family at the first level
- family – not single surface

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**Single Scalar Aggregates**

**Overview, statistics**
- first step
- reduce surface to minimum, maximum, median,…
- use common views to explore the data
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---

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Aggregated Profiles

General concept in data exploration – projection
- reduce dimensionality if you cannot show it

Profiles
- reduction operators
- project the surface to the plane
- min, max, median, average,... profiles

Analysis through aggregated profiles (drill down)
- advanced analysis
- very complex, challenging, and powerful
Aggregated Profiles

General
- reduce dimensionality if you cannot show it

Profiles
- reduction operators
- projection
- min, max, median, average, ...

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

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Aggregated Profiles

General
- reduce dimensionality if you cannot show it

Profiles
- reduction operators
- project the surface to the plane
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Analysis
- advanced analysis
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Surfaces

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Overview

Complex data: families of surfaces
- Meteorology
- Engineering
- Car racing

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groove Length</td>
<td>90, 112.5, 135, 157.5, 180, 202.5, 225, 247.5, 270</td>
<td>degrees</td>
</tr>
<tr>
<td>Groove Width</td>
<td>3, 3.5, 4, 4.5, 5</td>
<td>mm</td>
</tr>
<tr>
<td>Barrel Gap</td>
<td>0, 2.5, 5, 7.5, 10</td>
<td>microns</td>
</tr>
</tbody>
</table>

Table 2. Output values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Name</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing clearance height</td>
<td>CLEA</td>
<td>mm</td>
</tr>
<tr>
<td>Hydrodynamic pressure</td>
<td>PRES</td>
<td>MPa</td>
</tr>
<tr>
<td>Aspercity 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>FILL</td>
<td></td>
</tr>
<tr>
<td>Hydrodynamic shear stress</td>
<td>TAHS</td>
<td>MPa</td>
</tr>
<tr>
<td>Aspercity contact shear stress</td>
<td>TAAS</td>
<td>MPa</td>
</tr>
</tbody>
</table>

InfoVis, TU Wien, 2
Analysis snapshot 1

Krešimir Matković
InfoVis, TU Wien, 21. 04. 2015
Analysis snapshot 2

Krešimir Matković  InfoVis, TU Wien, 21. 04. 2015
Overview

Complex data: families of surfaces

- Meteorology
- Engineering
- Car racing

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

Simulation run:

- set five control parameters
- run simulation for 20 laps
- 5 different telemetry data stored at each sector

Common way of storing the data:

- table with \(20 \times 23 = 460\) rows
Single run

<table>
<thead>
<tr>
<th>Lap</th>
<th>Sector</th>
<th>Wing Angle</th>
<th>Brake Ratio</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>8</td>
<td>0.41</td>
<td>120</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>8</td>
<td>0.41</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>8</td>
<td>0.41</td>
<td>90</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>23</td>
<td>8</td>
<td>0.41</td>
<td>89</td>
</tr>
</tbody>
</table>

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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>
<th>...</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>8</td>
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<tr>
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<tr>
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<td>1</td>
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<tr>
<td>1</td>
<td>2</td>
<td>10</td>
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<tr>
<td>20</td>
<td>23</td>
<td>18</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

1. run
2. run
3. run

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InfoVis, TU Wien, 21. 04. 2015
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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Family of surfaces
Analysis of family of surfaces

Krešimir Matković
InfoVis, TU Wien, 21. 04. 2015
Analysis of family of surfaces

Krešimir Matković  InfoVis, TU Wien, 21. 04. 2015
Analysis of family of surfaces

Krešimir Matković  InfoVis, TU Wien, 21. 04. 2015
Family of surfaces - conclusion

Families of surfaces as a new data model

Who has families of surfaces?

(Almost) Everyone – but they are simplified because of lacking of technology

Interactive visual analysis offers new possibilities for analysis

Preconfigured views

3D view – show me the surface!

Krešimir Matković
InfoVis, TU Wien, 21. 04. 2015
Family of surfaces - conclusion

Who has families of surfaces?
(Almost) Everyone – but they are simplified because of lacking of technology

Interactive visual analysis offers new possibilities for analysis

- Preconfigured views
  - 3D view – show me the surface!

Krešimir Matković, InfoVis, TU Wien, 21.04.2015
Interactive Visual Analysis of Set-Typed Data

Wolfgang Freiler, Kresimir Matkovic, and Helwig Hauser

IEEE InfoVis 2008
Sets as dimension

Conventional approach deals with n-dim. Euclidian spaces

Each item is a point in n-dim. Space (n-tuple)

Set as dimension

New view

Demo!

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Days/or/Death</th>
<th>Status</th>
<th>Drug</th>
<th>Age/Days</th>
<th>Sex</th>
<th>Ascites</th>
<th>Hepatome</th>
<th>Spider</th>
<th>Edema</th>
<th>Bilirubin</th>
<th>Cholesterol</th>
<th>Albumin</th>
<th>Copper</th>
<th>Alpha</th>
<th>GOT</th>
<th>Triglic</th>
<th>Phosph</th>
<th>Pood lem</th>
<th>Time</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values</td>
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<td>0 / 1</td>
<td>0 / 1</td>
<td>int</td>
<td>int</td>
<td>int</td>
<td>int</td>
<td>int</td>
<td>int</td>
<td>int</td>
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<tr>
<td>400</td>
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<td>plac</td>
<td>31464</td>
<td>f</td>
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<td>1</td>
<td>1</td>
<td>1.0</td>
<td>15</td>
<td>261</td>
<td>2.6</td>
<td>156</td>
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<td>4</td>
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<td>alive</td>
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<td>0</td>
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<td>1</td>
<td>1.0</td>
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<td>302</td>
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<td>54</td>
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<td>3102</td>
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<td>1.4</td>
<td>176</td>
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<td>28</td>
<td>189</td>
<td>373</td>
<td>11</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8017</td>
<td>dead</td>
<td>plac</td>
<td>14291</td>
<td>m</td>
<td>0</td>
<td>1</td>
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<td>0.0</td>
<td>2.1</td>
<td>420</td>
<td>4</td>
<td>128</td>
<td>7119</td>
<td>222</td>
<td>220</td>
<td>70</td>
<td>10</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Set Type Data

Venn Diagrams introduced in 1880 by John Venn (1834–1923) in a paper entitled *On the Diagrammatic and Mechanical Representation of Propositions and Reasonings* in the "Philosophical Magazine and Journal of Science“ (from Wikipedia)

4 sets 5 sets 6 sets

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Set Type Data

Use of Histogram and Scatterplot – possible

Set-o-Gram

Demo!

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Set Type Data

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Set Type Data – Radial Sets

B. Alsallakh, W. Aigner, S. Miksch, and H. Hauser: Radial Sets: Interactive Visual Analysis of Large Overlapping Sets

Krešimir Matković
InfoVis, TU Wien, 21. 04. 2015
Set Type Data – Upset

Alexander Lex, Nils Gehlenborg, Hendrik Strobelt, Romain Vuillemot, and Hanspeter Pfister:
UpSet: Visualization of Intersecting Sets, IEEE TVCG 2014
Interactive Visual Steering

Krešimir Matković
InfoVis, TU Wien, 21. 04. 2015
InfoVis Reference Model

Data

Raw Data → Data Tables → Visual Structures → Views

Data Transformations → Visual Mappings → View Transformations

Human Interaction (controls)

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Motivation

Simulation

- widely used in science and engineering
- helps in understanding various phenomena
- recent trend:
  - multiple simulation runs
  - variation of various control parameters
  - study influence on output
  - understanding of simulation model
  - understanding of physical phenomena

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Simulation and Visualization 1

Common practice:
- define a model
- run simulation
- visualize results
- change the model
- run simulation ...
Simulation and Visualization 2

Multiple runs:

- define a model
- define control parameters
- run simulation
  - for each combination of control parameters
  - for some of the combinations (steering)
- use interactive visual analysis
  - to understand (optimize) the model
  - to understand the phenomena

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Interactive Visual Steering

Model, parameters, many simulation runs

How many is many?
- 11 parameters / 10 variations each
- $10^{11}$ combinations
- 10 simulations per minute (very fast) - $10^{10}$ minutes
- 19 000 years!

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Basic Idea

Start with a simple model

Assume the rest to be ideal

Tune the first model

Expand the model

Expand the model

…”

It is always possible to go back!

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Interactive Steering

3 loops
- Explore initial results set
- Change parameter values
- Change model

Tabular data
- Initial table
- Add / remove rows
- Add / remove columns
Interaction

3 loops

- A – real time interaction
- B – “live” parameter refinement (A loop functioning)
- C – model change - after initial runs and data management update same as B
First Step

Start with a simple model
Assume the rest to be ideal
Tune the first model
4 parameters, 750 combinations
12 minutes
Two targets
Interactive Visual Analysis

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Interactive Visual Analysis
Interactive Visual Analysis
Second Step
Second Step

Different responses

High CVsize – unwanted behavior

Narrow curves – low injected mass

No pilot injection

Same actuator!

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Second Step

Different responses

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Parameter refinement

Additional investigation needed

– refine parameters
Output at various steps

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Final model

Everything is set now
We wanted to check all output curves
Actuator variations
Interesting peaks detected!
Final solution

One operation point
Choose one and test
If everything OK – done!
Thank you!

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

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