

Interactive Visual Analysis of Complex Data: Families of Surfaces, Set Typed Data

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Overview 1

11. 05. 2011:

- Introduction
- Coordinated Multiple Views
- Complex data: families of curves
 - Engineering
 - VAST Challenge
 - Image Collections
 - Bio-signals

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Overview 2

18. 05. 2011:

- Summary of last lecture
- Complex data: families of surfaces
 - Meteorology
 - Engineering
 - Car racing
- Complex data: set typed data
- Model view integration
- Conclusion

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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 ...

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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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Meteorology model 1

Climate research at the PIK institute



Meteorology model 2

Time step	Diff_h	Diff_v	output 1	output2	...
1	Diffh	Diffv			
2	Diffh	Diffv			
3	Diffh	Diffv			
4			
...			

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, ...)

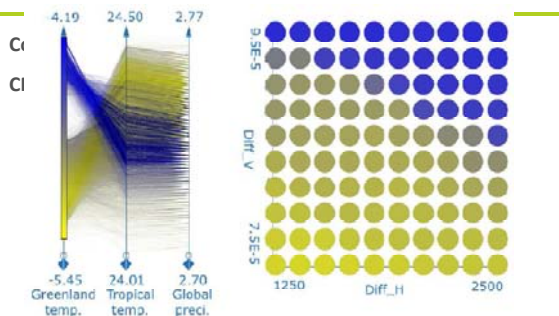
Common way of storing the data:

- multiply previous table 100 times, 50 000 rows now
- 3 independent variables now timestep, diffh, diffv

1. run
2. run
3. run

Time	Diff_h	Diff_v	output1	output2	...
1	dh1	dv1			
2	dh1	dv1			
...			
500	dh1	dv1			
1	dh1	dv2			
2	dh1	dv2			
...			
500	dh1	dv2			
1	dh1	dv3			
2	dh1	dv3			
...			
500	dh1	dv3			
...			
500	dh10	dv10			

Multiple runs - exploration



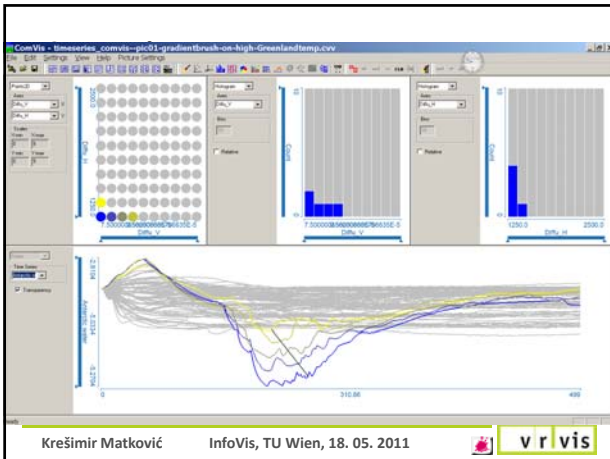
Mappings as dimensions - curves

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

Family of curves
↓

Run	Diff_h	Diff_v	Output1(t)	Output2(t)	...
1	dh1	dv1			
2	dh1	dv2			
3	dh1	dv3			
...			
100	dh10	dv10			



Mappings as dimensions - surfaces

Curves – we are interested about output as $f(\text{time})$

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

Group outputs from all runs in a “surface”

- e.g. temperature = $f(\text{diffh}, \text{diffv})$

Family of surfaces

500 rows now, one for each time step

Offers new possibilities for analysis

Timestep	Output1 (diffh, diffv)	Output2 (diffh, diffv)	...
1			
2			
...			
500			

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 through 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

level 1

level 2

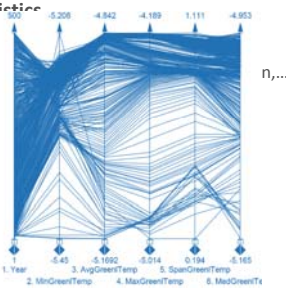
level 3

Single Scalar Aggregates

Overview, statistics

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

level 1



Aggregated Profiles

General

- redi

level 2

Pro

Analysis

- adv.
- very

Surfaces

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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

Parameter	Value	Unit
Journal length	96, 112, 132, 150, 180	micrometers
Groove width	3, 2.5, 4, 4.5, 5	micrometers
Barrel Gap	0, 2.5, 5, 7.5, 10	micrometers

Parameter	Name	Unit
Bearing clearance height	CLDIA	mm
Oil breakdown pressure	PRSA	MPa
Asperity contact pressure	PRSA	MPa
Fluid pressure	PRFL	MPa
Full film	PRFL	MPa
Oil breakdown shear stress	TASIS	MPa
Asperity contact shear stress	TASIS	MPa

- Bearing structure
 - Equation of motion $M \cdot \ddot{u} + D \cdot \dot{u} + K \cdot u = F_{load}$
- Oil film
 - Reynolds equation $\frac{\partial}{\partial x} \left(\frac{h^3}{12\eta} \frac{\partial p}{\partial x} \right) + \frac{\partial}{\partial z} \left(\frac{h^3}{12\eta} \frac{\partial p}{\partial z} \right) = 2 \frac{\partial h}{\partial t} + u \frac{\partial h}{\partial x} + v \frac{\partial h}{\partial y}$
- Journal structure
 - Equation of motion $M \cdot \ddot{u} + K \cdot u = F_{load}$
 - rigid journal $M \cdot \ddot{u} + K \cdot u = F_{load}$
 - flexible journal $M \cdot \ddot{u} + K \cdot u = F_{load}$

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Analysis snapshot 1

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Analysis snapshot 2

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Family of surfaces - conclusion

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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

Lap	Sector	Wing Angle	Brake Ratio	...	Speed
1	1	8	0.41		120
1	2	8	0.41		100
1	3	8	0.41		90
...			
20	23	8	0.41		89

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

1. run

2. run

3. run

Lap	Sector	Wing Angle	Break Ratio	...	Speed
1	1	8			
1	2	8			
...			
20	23	8			
1	1	10			
1	2	10			
...			
20	23	10			
1	1	12			
1	2	12			
...			
20	23	12			
...			
20	23	18			

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

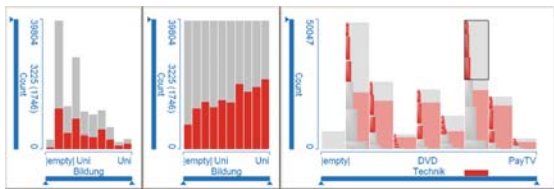
Offers new possibilities for analysis

Family of surfaces



Run	Wing Angle	Speed(lap,sector)	...
1	8		
2	8		
...	...		

Set Type Data



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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

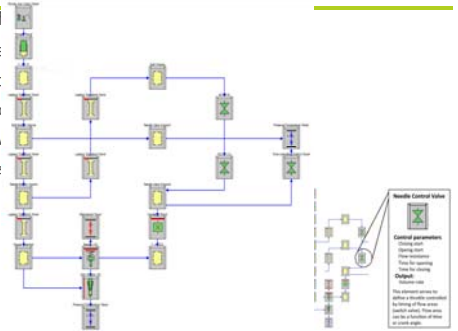
- emission reduction
- engine efficiency



Model

Model definition

- standard
- each block
- state variables



Multiple simulation runs

AVL Hydram tool used

1D CFD – fast simulation

- 10 simulation runs per minutes

7 parameters varied – 2880 runs

9 state variables considered in analysis (+ aggregates)

Block	Parameter	Values
H	flow resistance	1.0; 2.0; 3.0; 4.0
I	flow resistance	1.0; 2.0; 3.0; 4.0
E	flow resistance	1.0; 2.0; 3.0
B	flow resistance	1.0; 2.0; 3.0
G	closing starts	20; 25; 30; 35; 40
G	opening starts	-15; -20; -25
H	opening starts	-15; -20

Block	Parameter	Units
A	pressure	bar
A	volume rate	mm ³ /deg
G	volume rate	mm ³ /deg
C	lift	mm
C	velocity	m/s
D	volume rate	mm ³ /deg
D	injected volume	mm ³
D	pressure	bar
F	pressure	bar

Data

One record = one run

Various attributes

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

Family of curves

Run	Flow resistance	Closing start	Pressure(t)	Velocity(t)	...
1	1	20			
2	1	25			
3	1	30			
...			
2880	4	40			

Interactive Visual Analysis

Results

- use
- CM
- ma
- eng

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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

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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

Level two

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

Level three

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

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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

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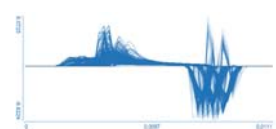
Analysis – the High Power Mode 3

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

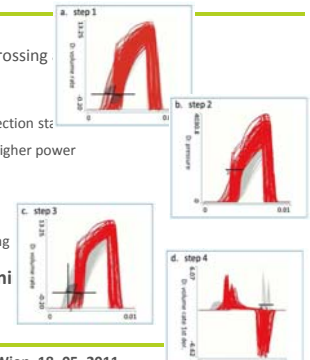
Refine selection

- only high pressure at the injection stroke
- Stronger fuel penetration – higher power

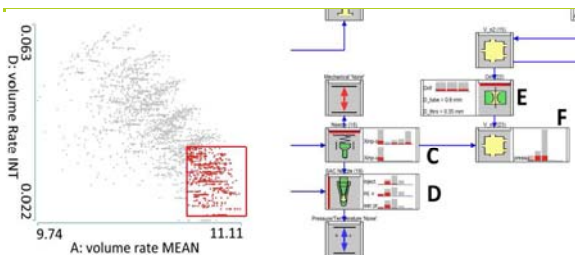
Refine once more

- subtract too slow rising
- or change limit of the crossing

Exclude second needle opening



Analysis – the High Power Mode 5



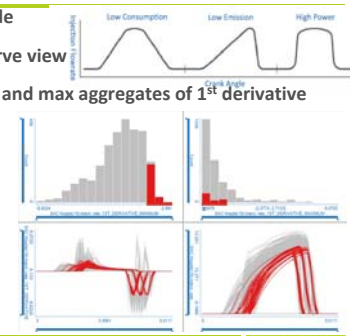
All parameters are always highlighted in the model view

Unlimited Possibilities

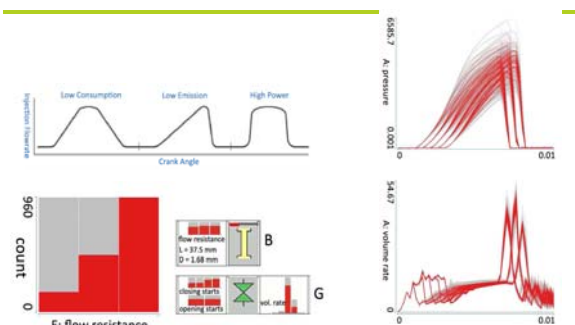
Low Consumption mode

Instead of brushing curve view

Use histograms of min and max aggregates of 1st derivative



Further Operation Modes



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

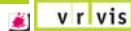
Families of curves, surfaces, sets

- 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, ...

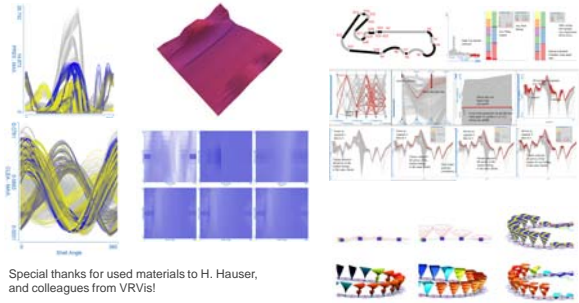
Ideas

Praktikums - Diplomaarbeiten

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Thank you!



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