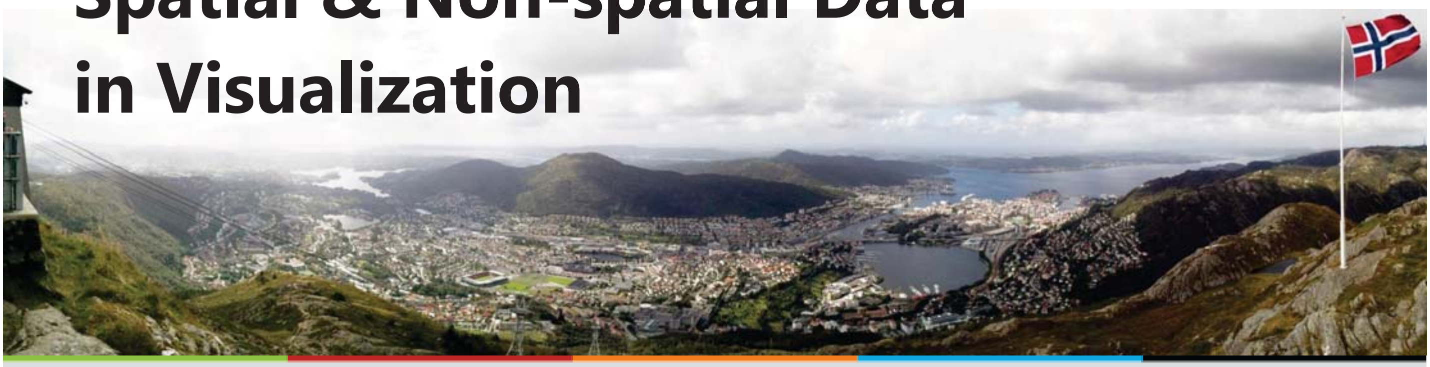
Integrating Spatial & Non-spatial Data in Visualization



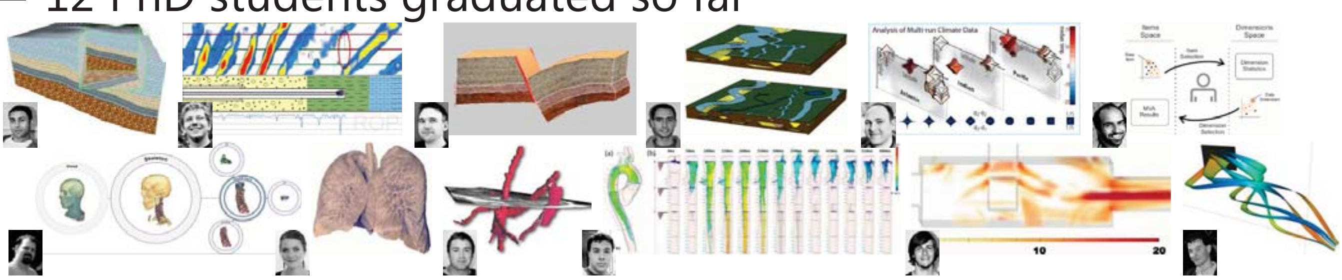
Helwig Hauser

University of Bergen

HH/Bergen/...

Prof. in visualization @ UiB since 2007

- vis. @ UiB.no/ii: 1 of 6 res. groups in CS
- 2 profs., 1 res. eng., 1 PostDoc, 4 PhD studs., 5 adjunct res., 2 visiting res.
- 12 PhD students graduated so far



Background from Vienna! :–)

- PhD (in flow vis.) from TU Wien (1998)
- @ VRVis 2000–2007

Spatial Data (or so)

Data with a central relation to space

- spatial measurements
- numerical simulation wrt. space (& time)
- …

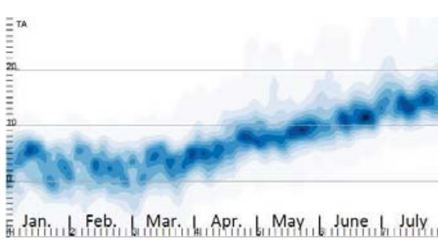
Selected related tasks

- where (in space)
  is a particular feature?
  (feature location)
- what data is
  in a particular location?
  (local investigation)

Non-spatial Data (or so)

Other data (a possible relation to space is not central)

- tabular data (spreadsheets, …)
- time series data
- …



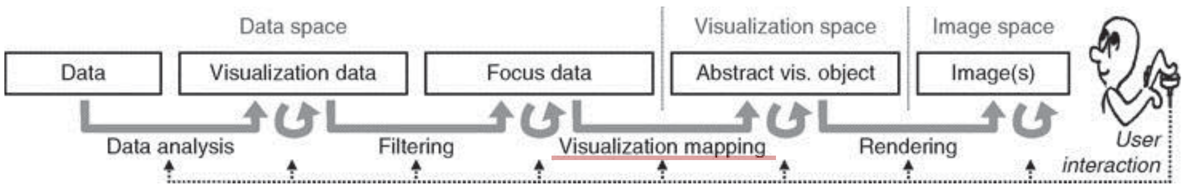
	1	2	3	4	5	6	7	8
1	OBS.	TOWN	TOWN#	LON	LAT	MEDV	RAD	CRIM
2	1	Nahant	0	-70.955	42.255	24	1	0.00632
3	2	Swampsc	1	-70.95	42.2875	21.6	2	0.02731
4	3	Swampsc	1	-70.936	42.283	34.7	2	0.02729
5	4	Marblehe	2	-70.928	42.293	33.4	3	0.03237
6	5	Marblehe	2	-70.922	42.298	36.2	3	0.06905
7	6	Marblehe	2	-70.9165	42.304	28.7	3	0.02985
8	7	Salem	3	-70.936	42.297	22.9	5	0.08829
9	8	Salem	3	-70.9375	42.31	27.1	5	0.14455
10	9	Salem	3	-70.933	42.312	16.5	5	0.21124
11	10	Salem	3	-70.929	42.316	18.9	5	0.17004
12	11	Salem	3	-70.935	42.316	15	5	0.22489
13	12	Salem	3	-70.944	42.317	18.9	5	0.11747
14	13	Salem	3	-70.951	42.306	21.7	5	0.09378
15	14	Lynn	4	-70.9645	42.292	20.4	4	0.62976
16	15	Lynn	4	-70.972	42.287	18.2	4	0.63796
17	16	Lynn	4	-70.9765	42.294	19.9	4	0.62739
18	17	Lynn	4	-70.987	42.2985	23.1	4	1.05393
19	18	Lynn	4	-70.978	42.285	17.5	4	0.7842
20	19	Lynn	4	-70.9925	42.2825	20.2	4	0.80271
21	20	Lynn	4	-70.988	42.2776	18.2	4	0.7258
22	21	Lynn	4	-70.9835	42.277	13.6	4	1.25179

Selected related tasks

- is the set of data items structured?
  (clusters? outliers? …)
- what's the intrinsic dimensionality of the data?
  (lower-dimensional embedding? representative factors?)

Visualization (or so) :–)

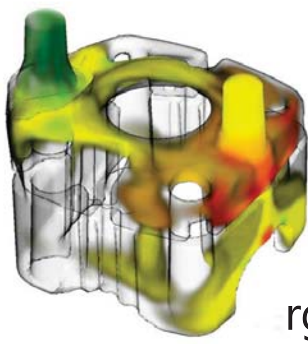
VisPipe



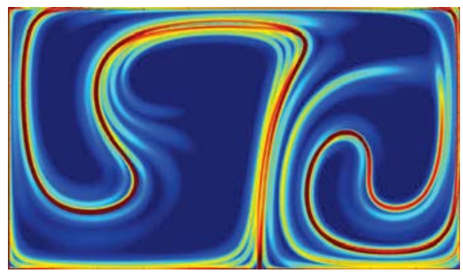
according to: Chi E.H. A taxonomy of visualization techniques using the data state reference model. In Proc. IEEE Symp. on Information Visualization, 2000, pp. 69–75. | dos Santos S. and Brodlie K. Gaining understanding of multivariate and multidimensional data through visualization. Computer & Graphics, 28(3):311–325, 2004.

Visualization mapping critical

- mapping from data space into visualization space
- visualization: rgbα(nD) with $n = 3$ or 2 or geometry in nD …



α: TKE
rgb: pressure

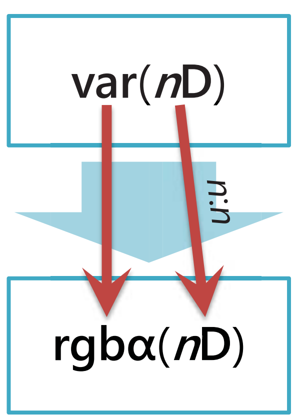


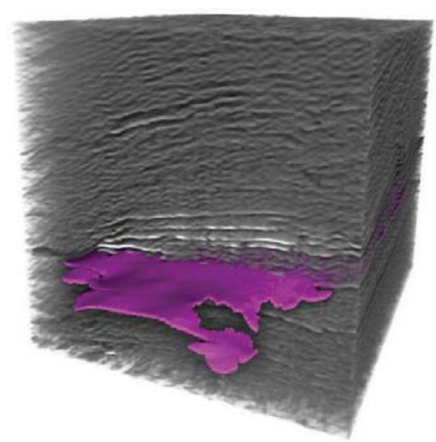
rgb: FTLE

Traditional Spatial Data Visualization

Ref.-space → vis.-space

"SciVis"? or "FooVis"?



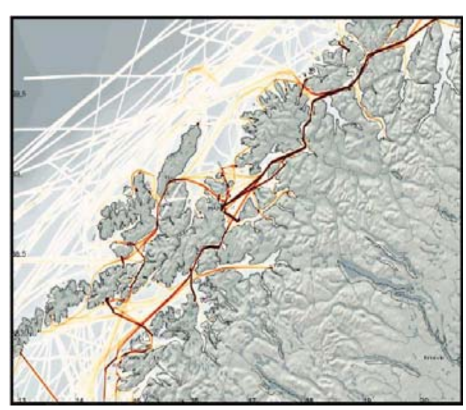


In 3D

- 3D (or 2D) visualization, for ex., by volume rendering, etc.

In 2D

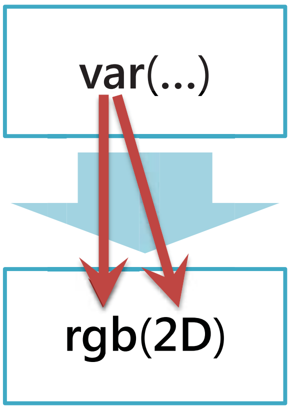
- 2D (or 3D) visualization, for ex., in geospatial data visualization

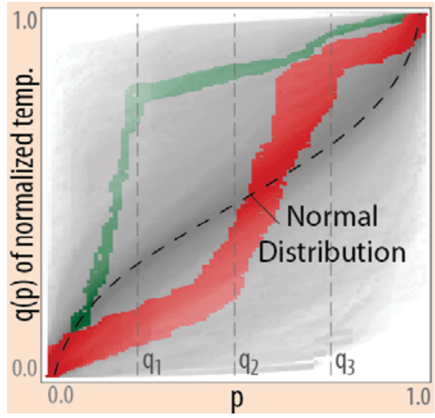


Usual Non-spatial Data Visualization

Variables → vis.-space

"InfoVis"?



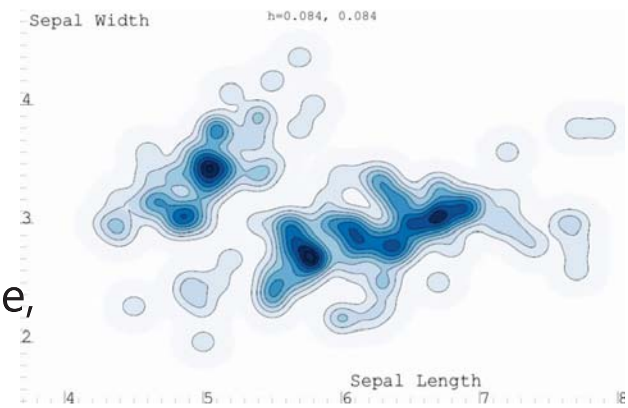


Item-based

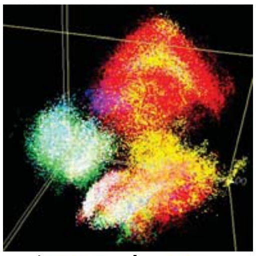
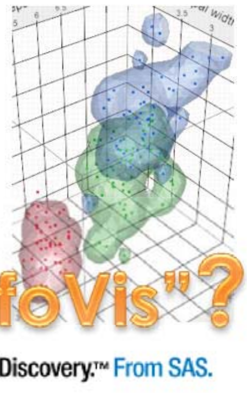
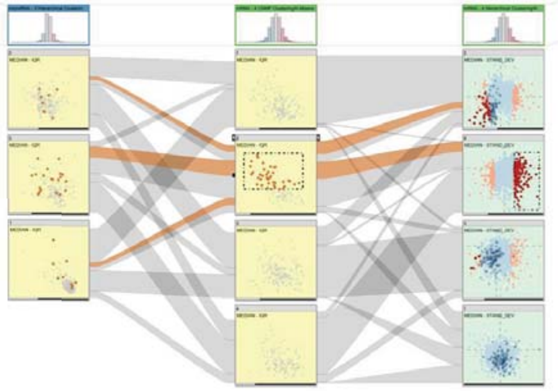
- a visual element per data item, e.g., via a scatterplot

Frequency-based

- rgb represent a density estimate, for ex., via a KDE plot



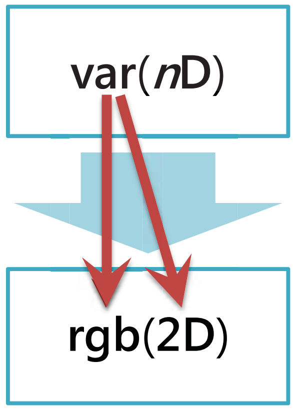
Data vs. Visualization Approach

Data	"SciVis"?	"InfoVis"?
Spatial Data		
Non-Spatial Data	 Reina, Ertl (2004) 	

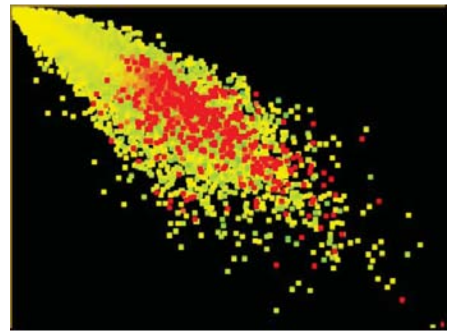
Non-spatial Spatial Data Visualization

Variables → vis.-space

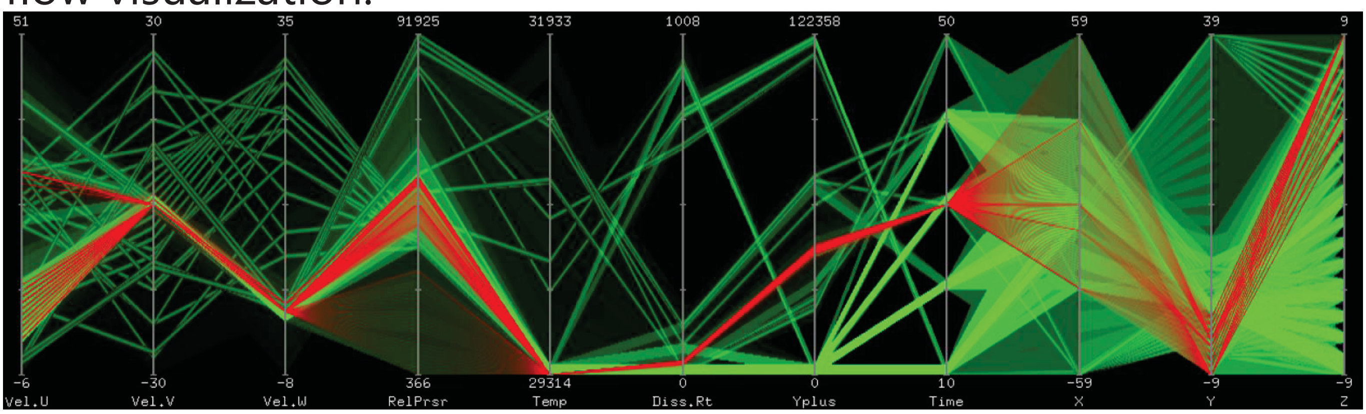
"InfoSciVis"?



medical visualization:



flow visualization:

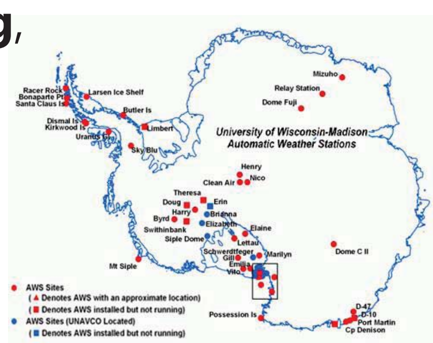


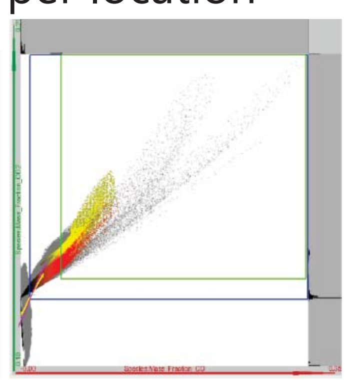
Spatial vs. Non-spatial, SciVis vs. InfoVis?

Spatial data: **spatiality central**
Non-spatial data: **spatiality not central** **– a binary Q??**

– numerical simulation data: **many attributes** per location

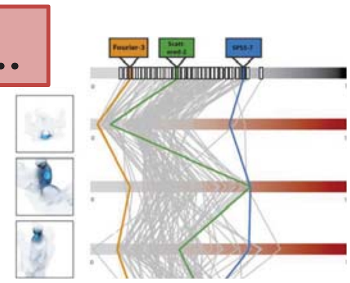
– **sparse spatial sampling**, for ex., weather stations





SciVis vs. InfoVis: **more two communities …**

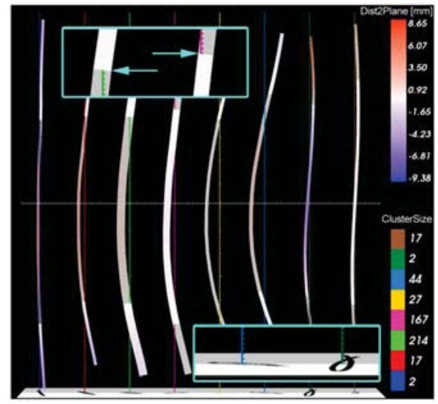
– lots of **InfoSciVis at VAST**, for ex.



Two Selected Challenges

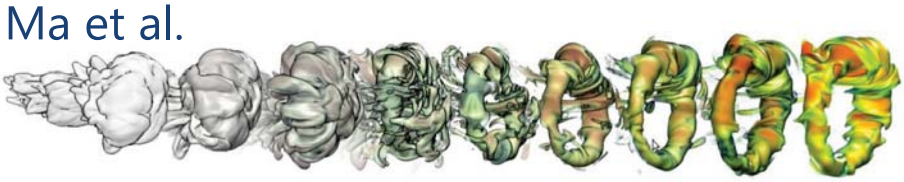
From one to many

- spatial data from entire cohort studies
- exploiting ensemble simulation data
- …

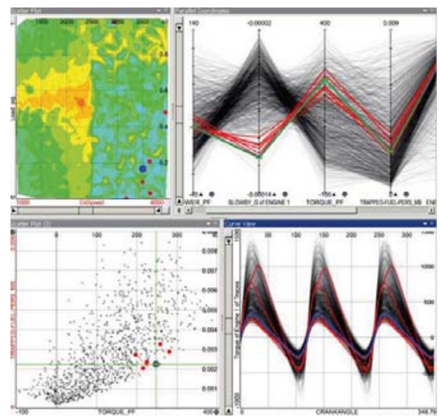


Preim et al.

Ma et al.



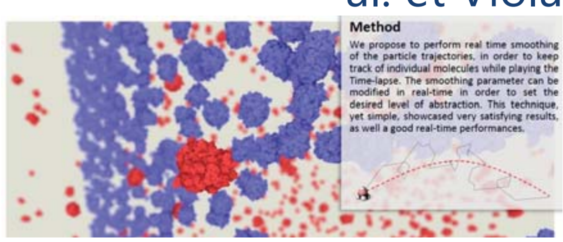
VRVis



Dynamic spatial data

- in one image
- very long sequences
- …

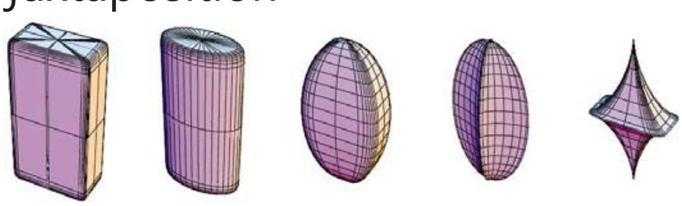
al. et Viola



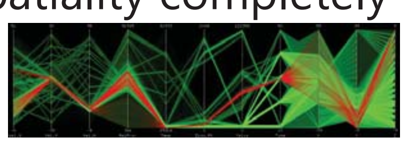
Visualizing Many Spatial Datasets

Mapping trade-off:

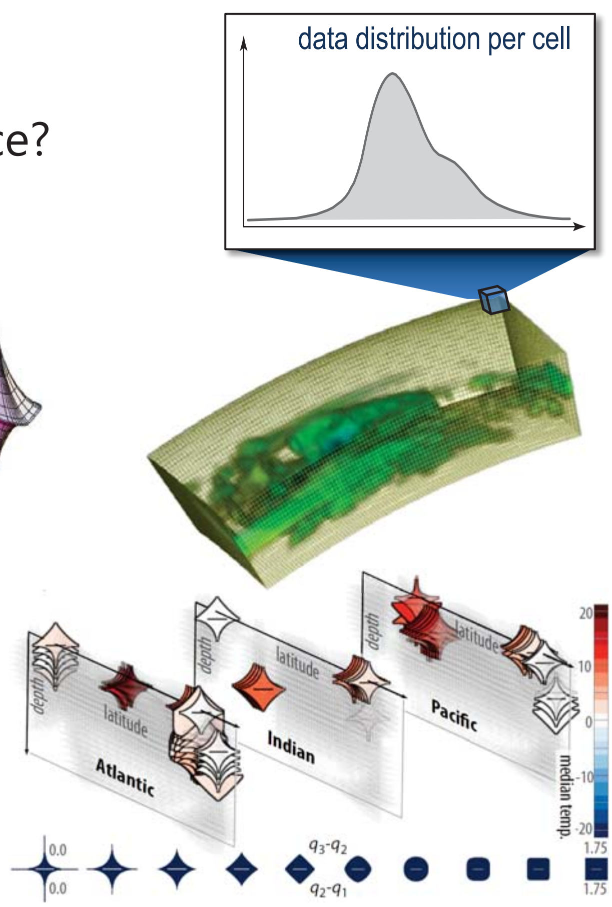
- how to use the visualization space?
  - show statistics per location
  - juxtaposition



  - abstract spatiality completely
  - …



- how much vis.-space
  - for the spatial aspects?
  - for the non-spatial aspects?



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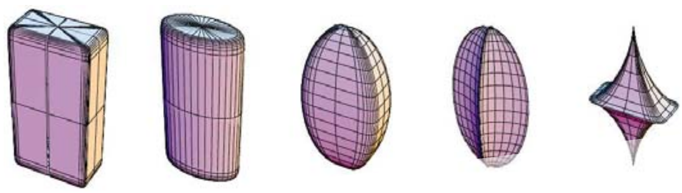
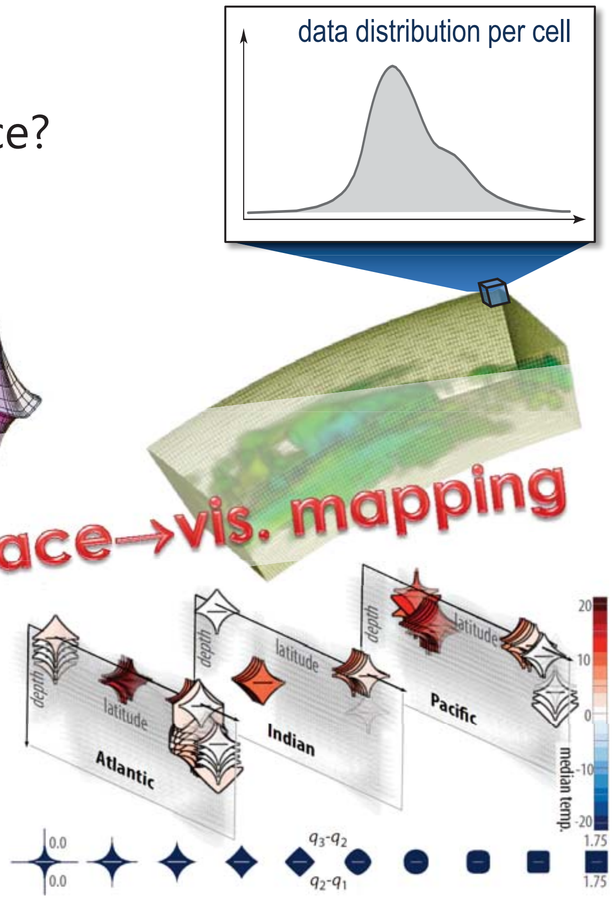


  - abstract spatiality completely
  - …

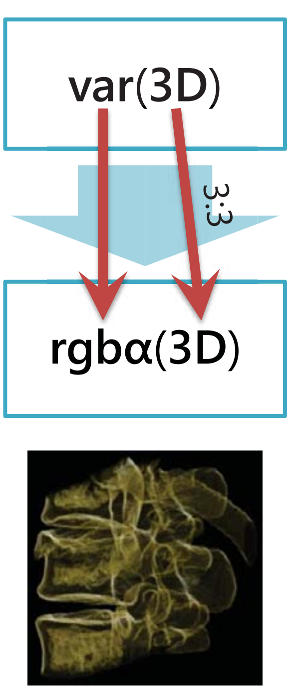
Let's consider that we need (some) space→vis. mapping

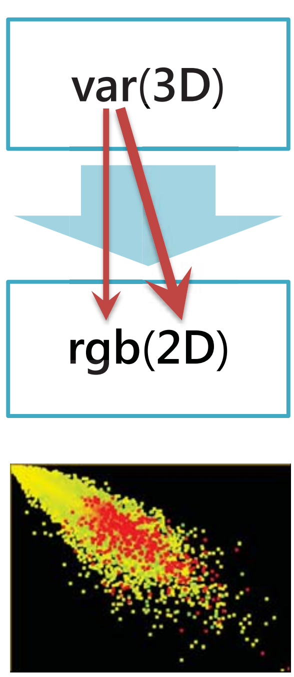
– how much vis.-space
  - for the spatial aspects?
  - for the non-spatial aspects?

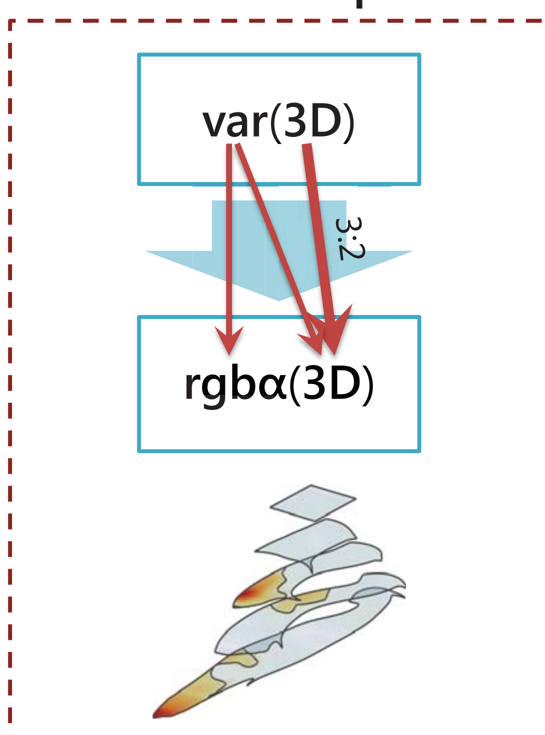


Semi-abstract Spatial Data Visualization

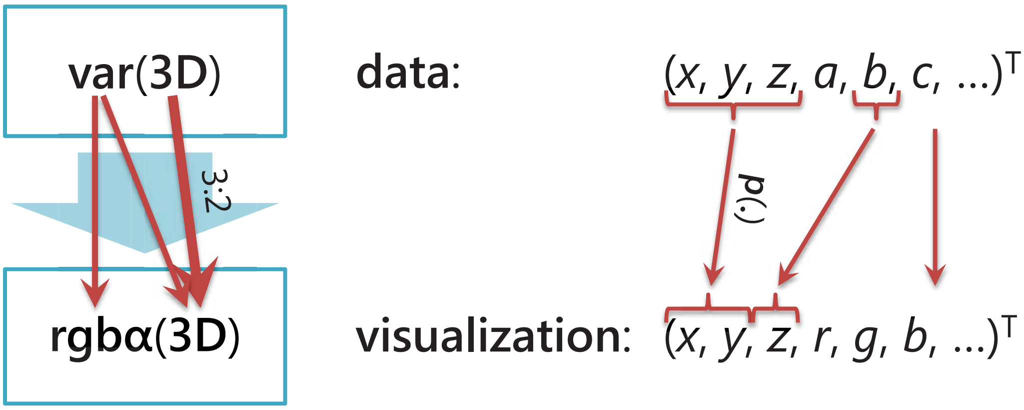
Mapping the spatial aspects to a subset of the vis.-space, using the other subset to represent other data aspects







Partial Spatial Abstraction

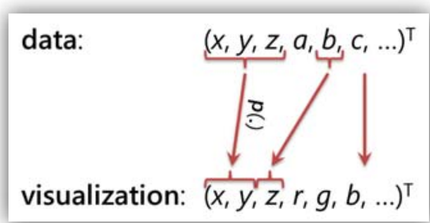


Lower-dimensional embedding p(.) of the spatial aspects

- by projection
- by transformation
- by abstraction

Additional space for alternative data aspects, *e.g.*, "*b*"

Mapping Compression Trade-off



Prize:

- "lossy" **p**(.) – data's spatiality not 100% represented

Potential benefit:

- comparative visualization of multiple phenomena
- single-picture summary of time-dependent data
  - devoting one vis.-space axis to time
- crossing SciVis with InfoVis
  - putting a function graph onto a spatial abstraction
  - visualizing statistics across a spatial abstraction

The real voyage of discovery
consists not in seeking new landscapes,
but in having new eyes.

Marcel Proust (1871—1927)

Example: log-log plot

Grand visualization in relation to power laws

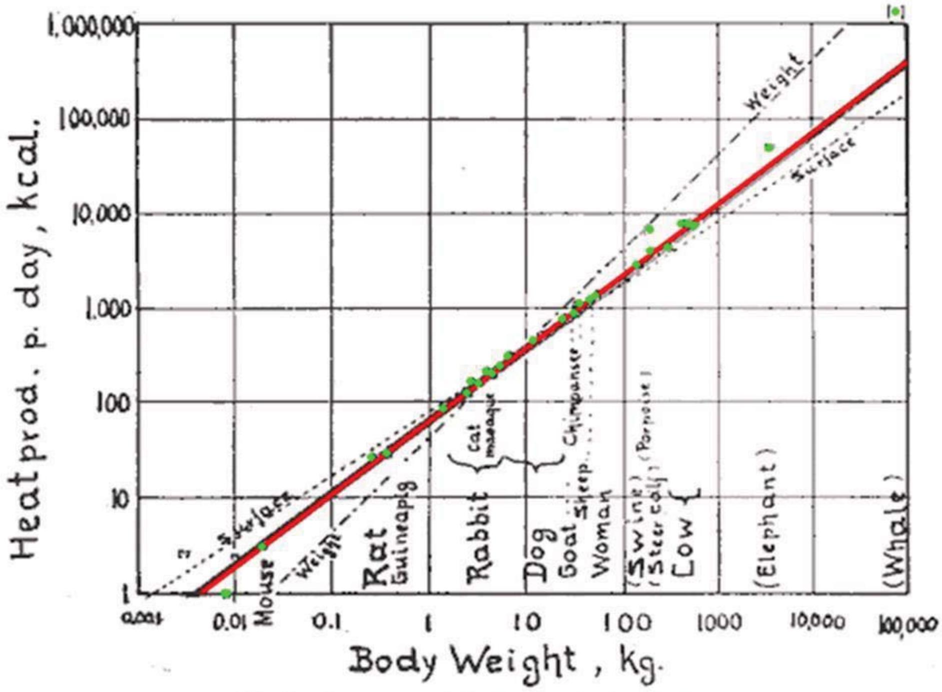


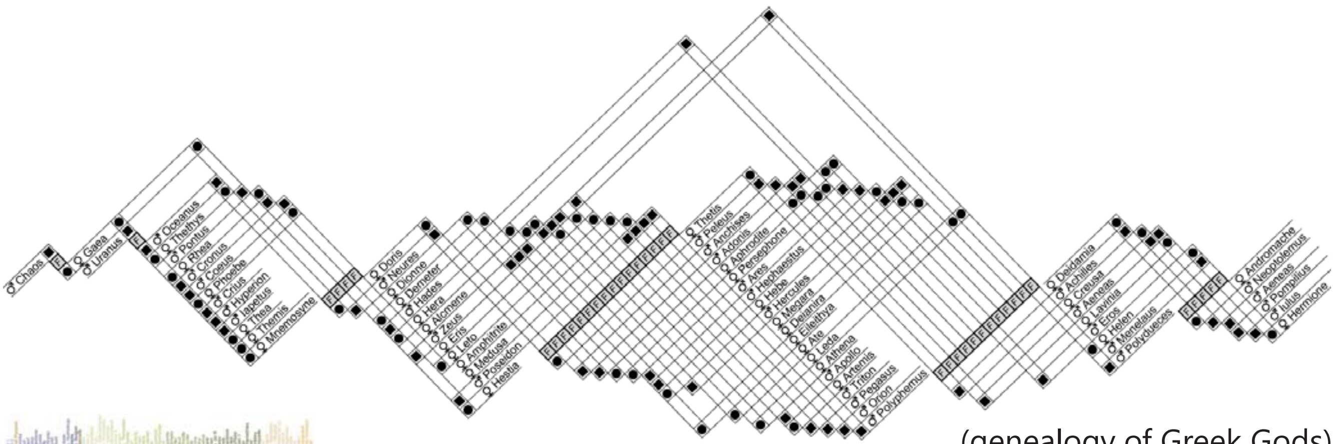
Fig. 1. Log. metabol. rate/log body weight

[«Body Size and Metabolic Rate» by M. Kleiber, Physiological Reviews, 1947]

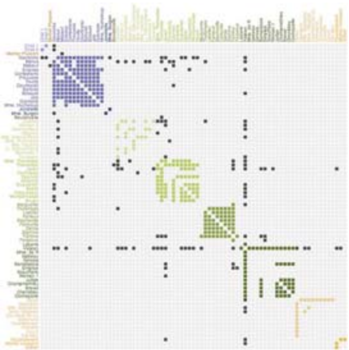
Example: adjecency matrix visualization

Revealing insight into large graphs – here: GeneaQuilts

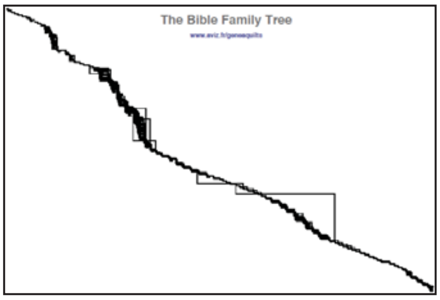
[«GeneaQuilts: A System for Exploring Large Genealogies» by A. Bezerianos, TVCG, 2010]



(genealogy of Greek Gods)

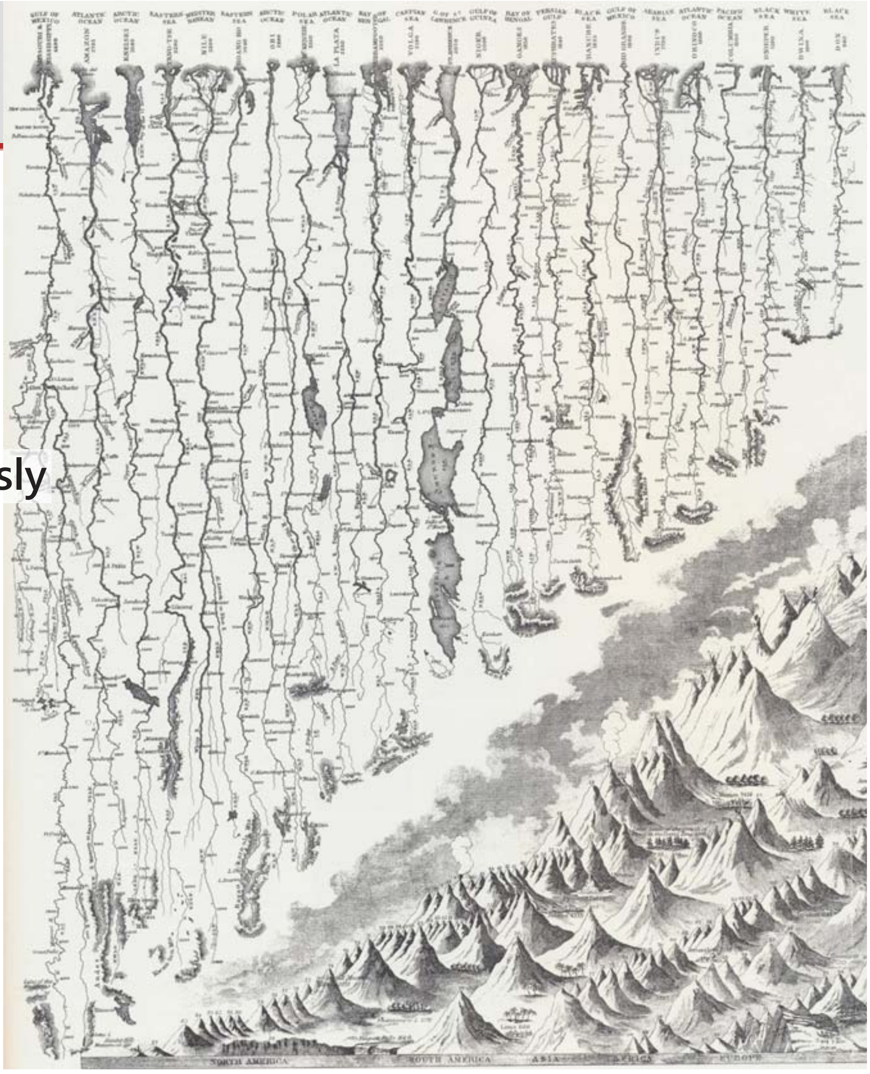


(character interaction in Les Misérables)



Tufte, 1997

“Spatial parallelism takes advantage of our notable capacity to compare and reason about multiple images that appear simultaneously within our eyespan”



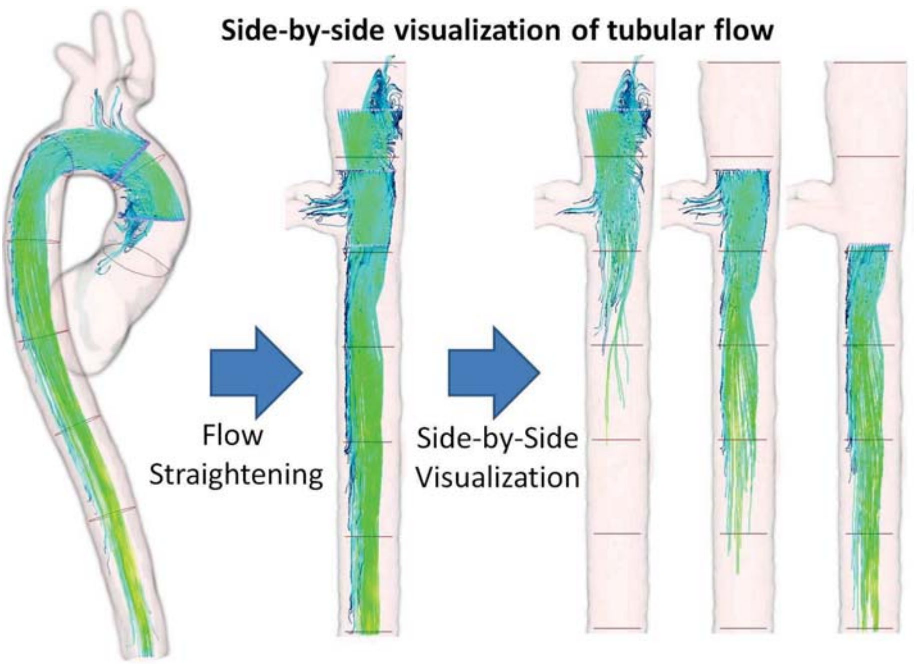
[«Visual Explanations: Images and Quantities, Evidence and Narrative» by E. R. Tufte, Graphics Press 1997]

Three recent examples

VisGroup Bergen *et al.*

Straightening tubular flow example

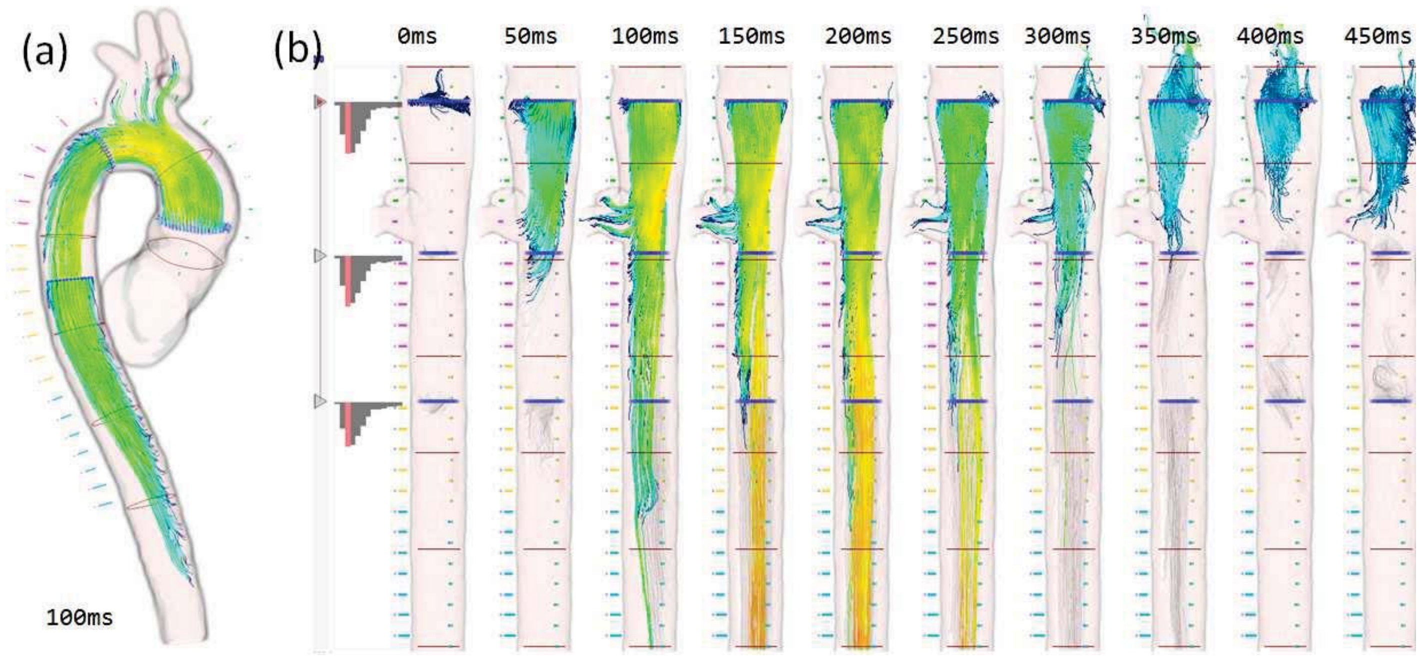
Reforming a 3D flow field such that a reference curve straightens



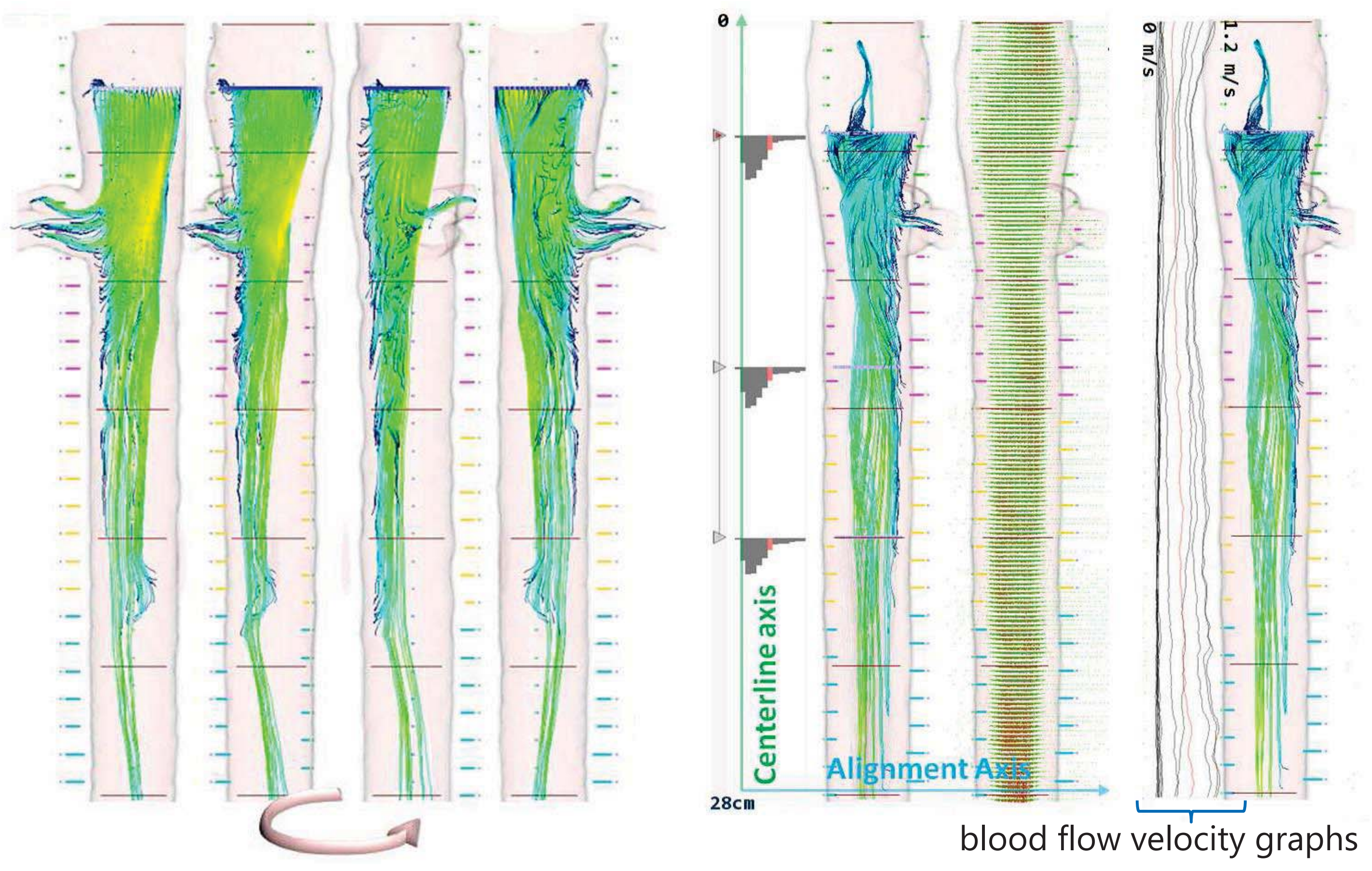
[«Straightening Tubular Flow for Side-by-Side Visualization»
by Paolo Angelelli *& HH*, TVCG 2011]

Semi-abstract straightened FlowVis

Side-by-side summary of time-dep. aortic blood flow

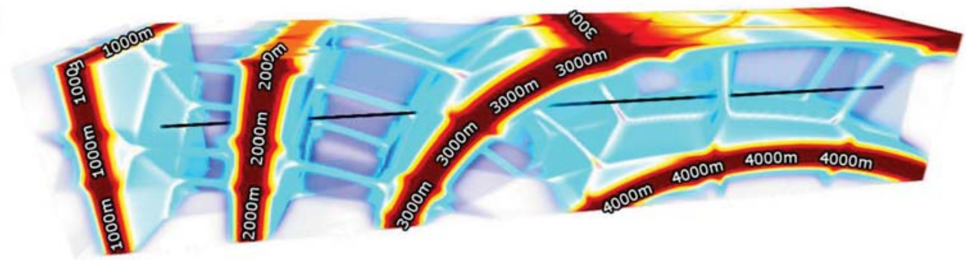


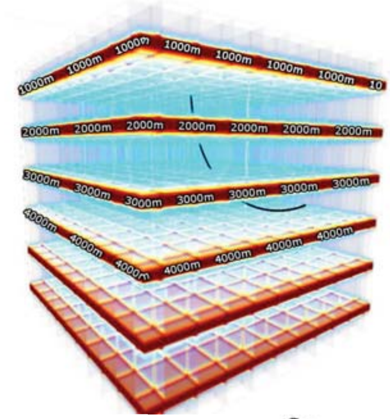
Semi-abstract straightened FlowVis



Curve-centric volume reformation example

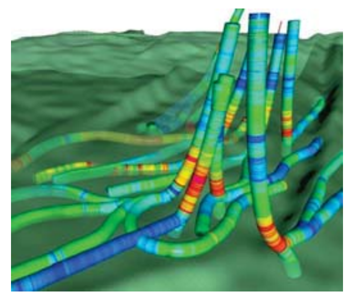
Reforming a data volume such that a reference curve straightens

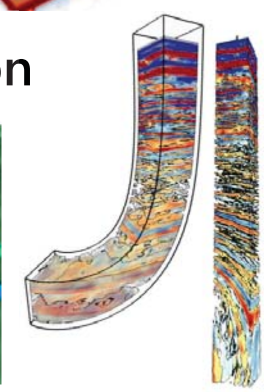




Application context: bore hole data visualization

– lots of data from drilling, incl.
  - 3D seismic data
  - US borehole images
  - drilling process data

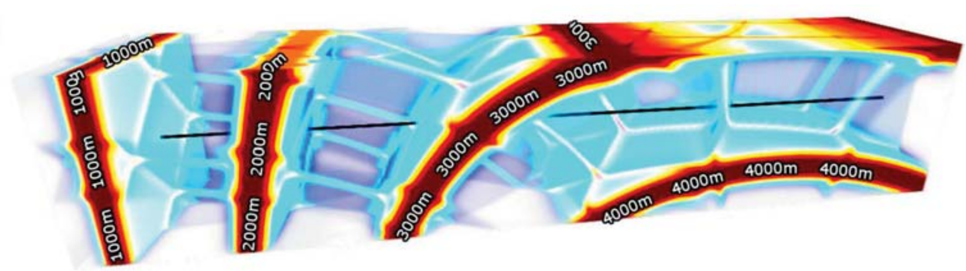


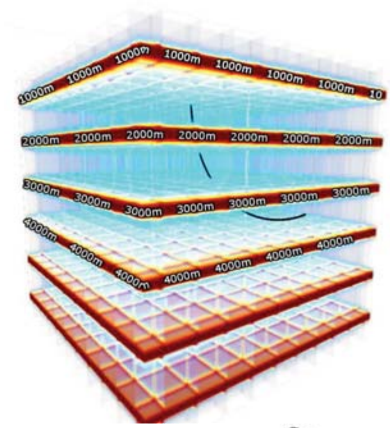


[«Curve-Centric Volume Reformation for Comparative Visualization» by Ove Daae Lampe *et al.*, TVCG 2009]

Curve-centric volume reformation example

Reforming a data volume such that a reference curve straightens





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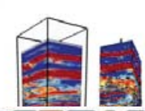
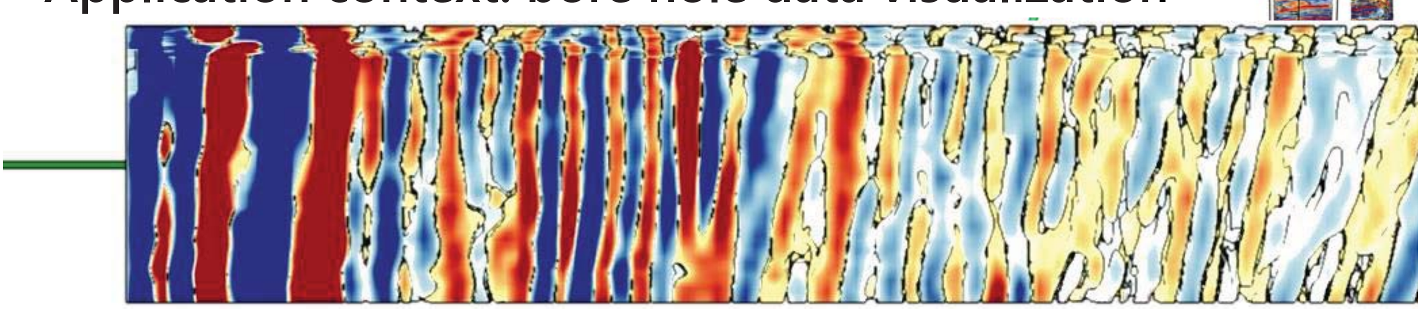
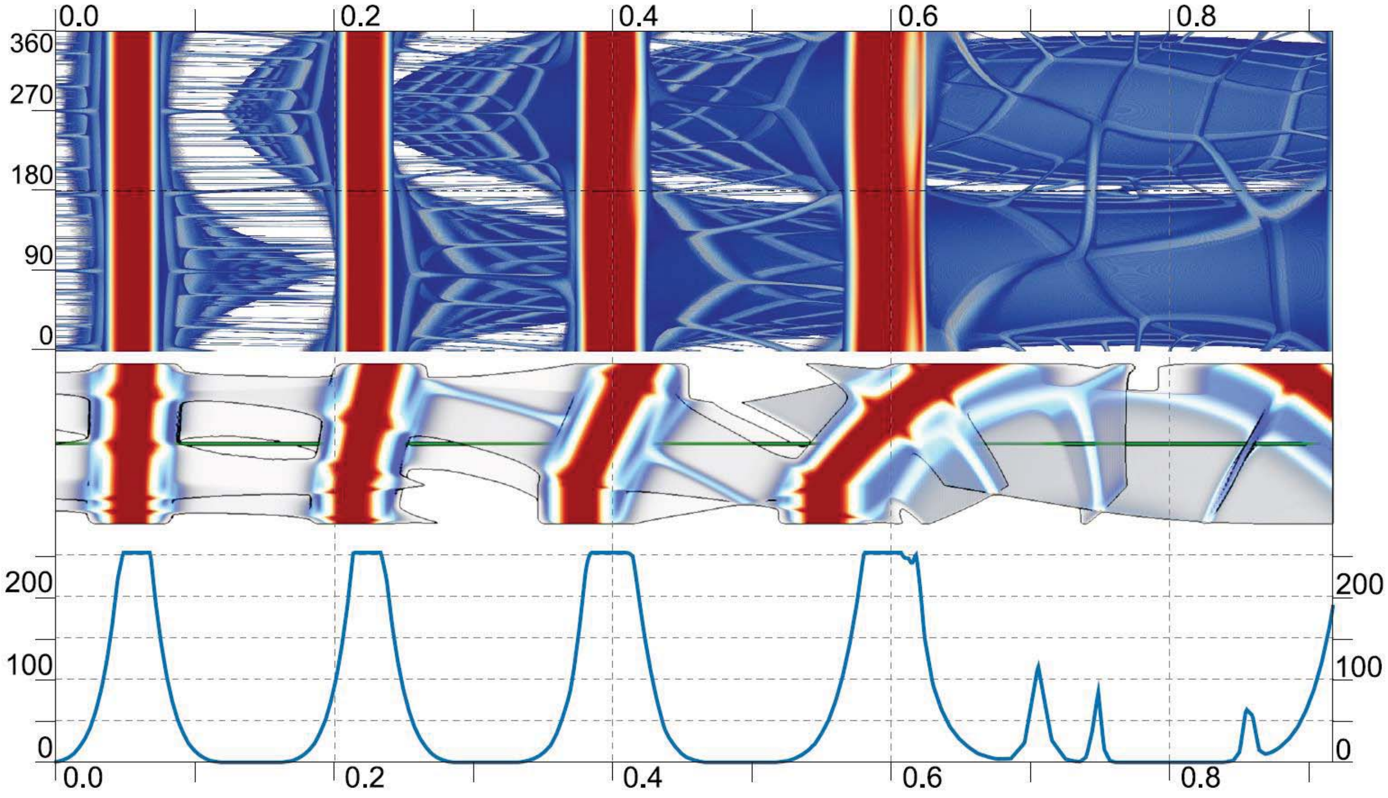




[«Curve-Centric Volume Reformation for Comparative Visualization» by Ove Daae Lampe *et al.*, TVCG 2009]

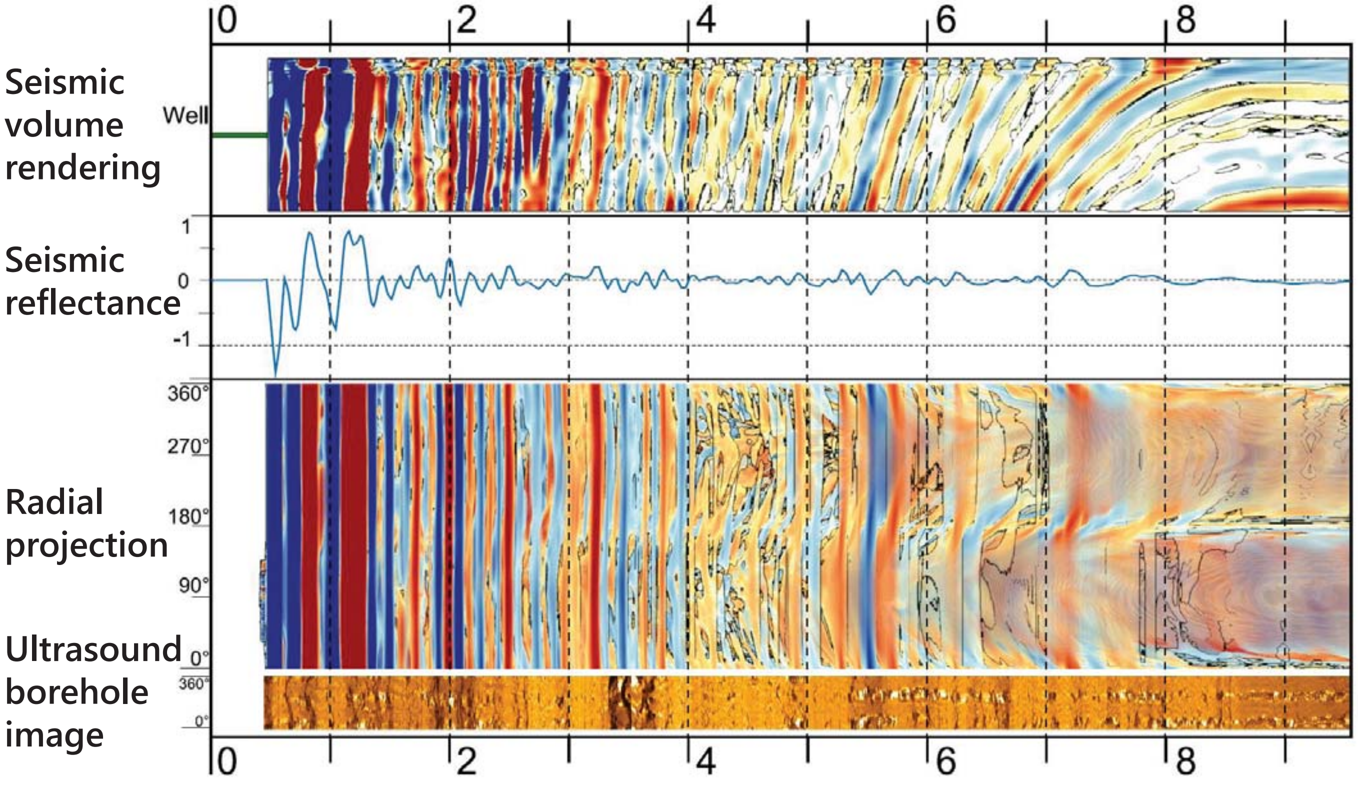
Semi-abstract CCVR-based visualization

Radial projection + volume rendering + density graph



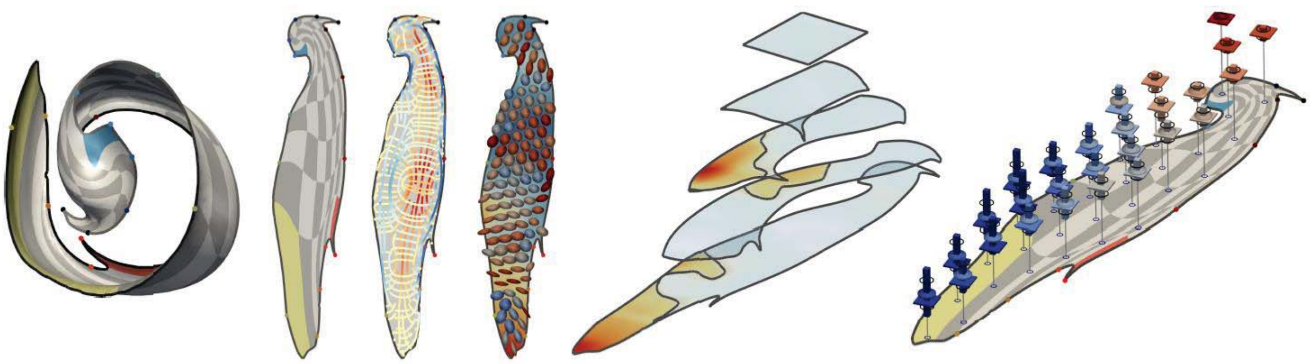
Semi-abstract CCVR-based visualization

Seismic VR & seismic reflectance & RadProj & UBI



Planar surface reformation example

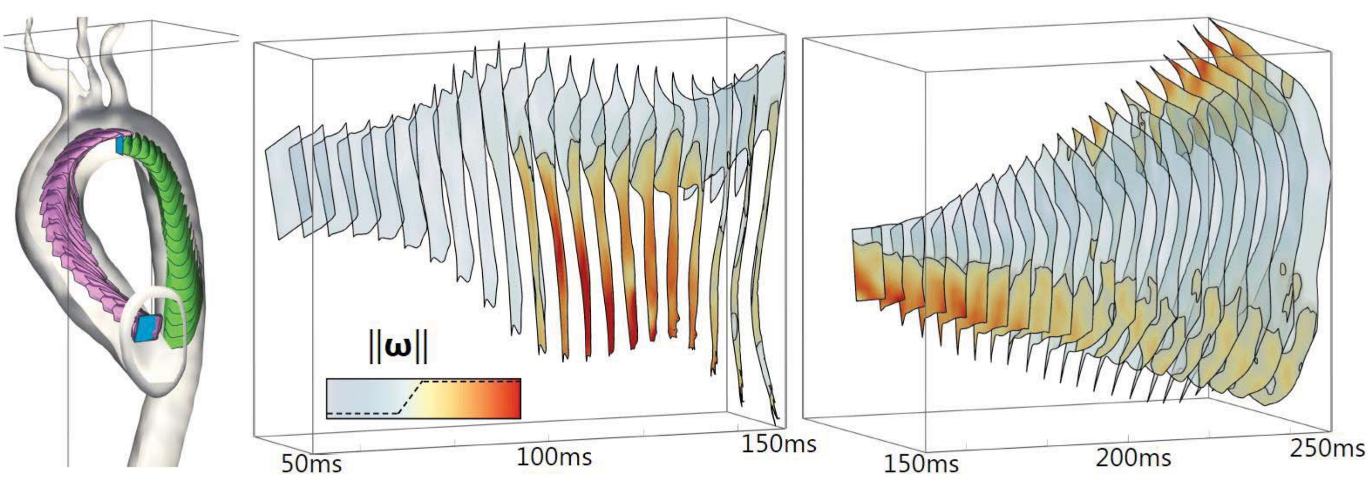
Reforming time surfaces from 3D to 2D to enable comparative visualization

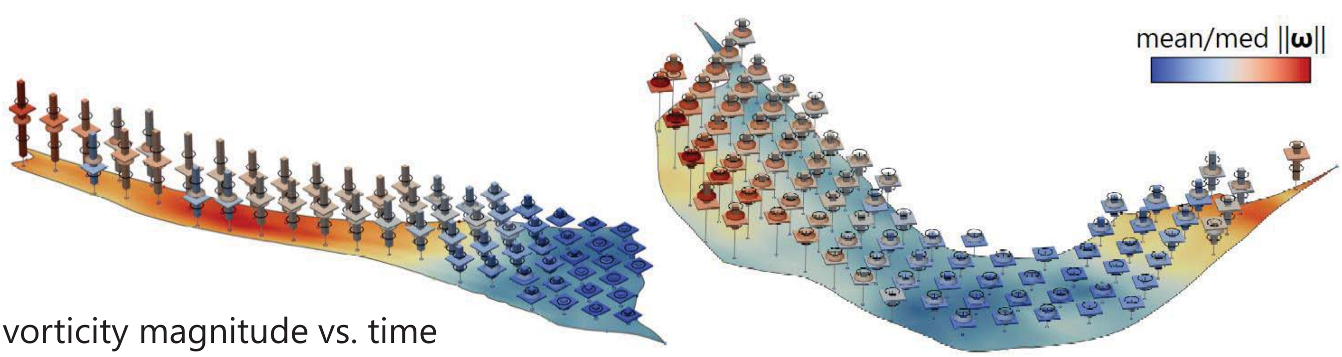


time surface in 3D — time surface in 2D (3*) — flattened time surfaces, stacked in 3D — statistical flow vis., with ref. to a flattened time surface in 3D

[«Comparative Flow Visualization via Multiple Time Surfaces using a Planar Surface Reformation» by Andrea Brambilla *et al.*, about to be rejected 2014]

Semi-abstract unsteady FlowVis

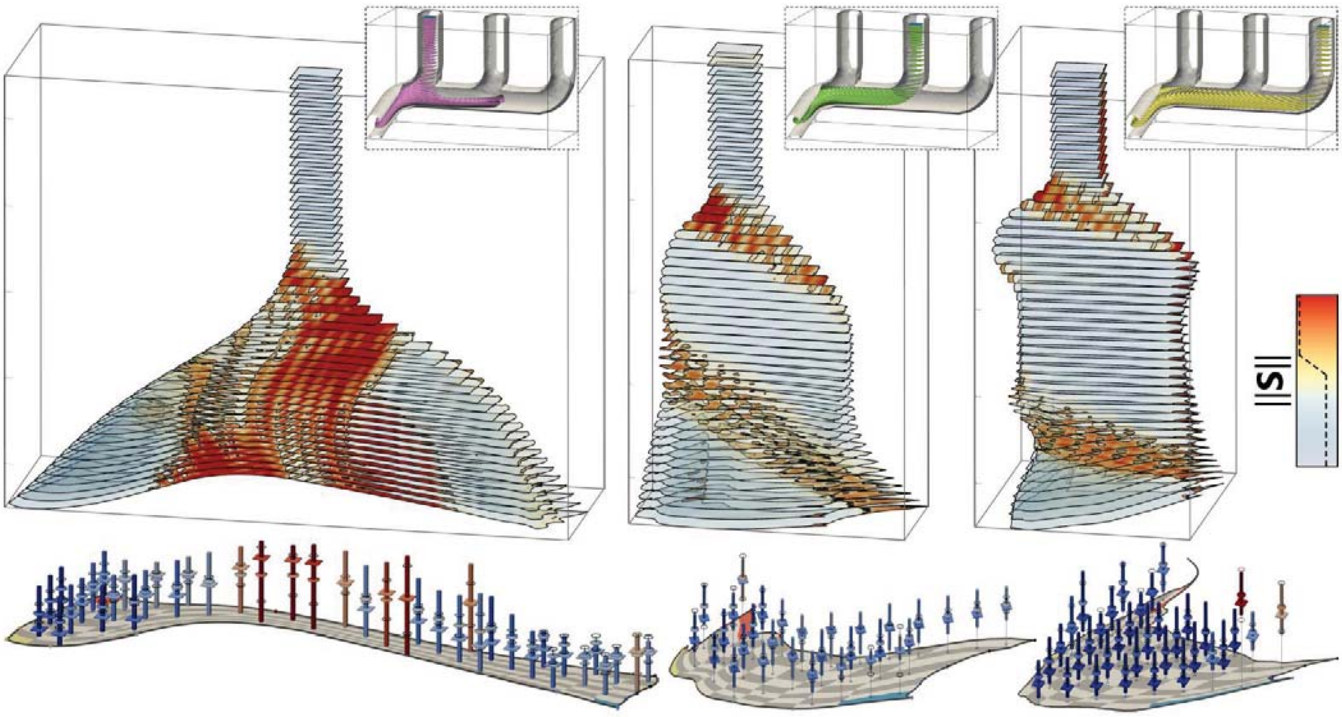




vorticity magnitude vs. time

Semi-abstract unsteady FlowVis

Time-dependent flow through an exhaust manifold



statistical visualization of strain along trajectories over time over last time surface

Modeling this Trade-off & Optimization

What's the optimal trade-off?

– what means optimal?

Model

– can we characterize/measure the relevance of spatiality?

– what to automize?

Optimzation

– semi-automatic optimization of a comparative visualization design

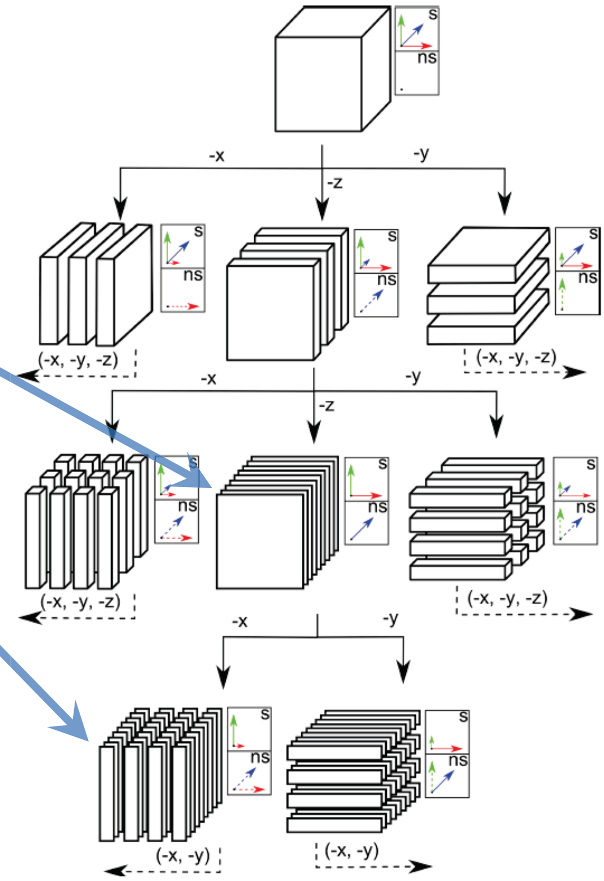
Choices

How lossy should p(.) be?

– from 3D to 2D?
– from 3D to 1D?
– from *n*D to 1.5D?

How much for *b*?

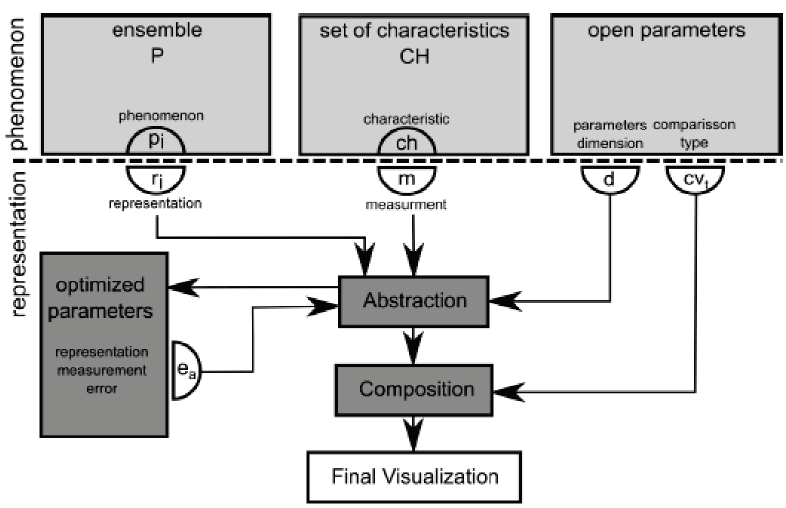
– 1D?
– 2D?
– (*n*−3/2)D?



Model

User, phenomenon, characteristics

– objects of interest; an ensemble
– (spatial) aspects of interest



vs. representation, measurements

– data (model) representation to work with, e.g., through imaging, num. sim., …
– measures (representing relevant characteristics), computed from the data (mode)

Sandbox Example

Imaginary context:

– ivy-loving grandmothers

focus:
natural look

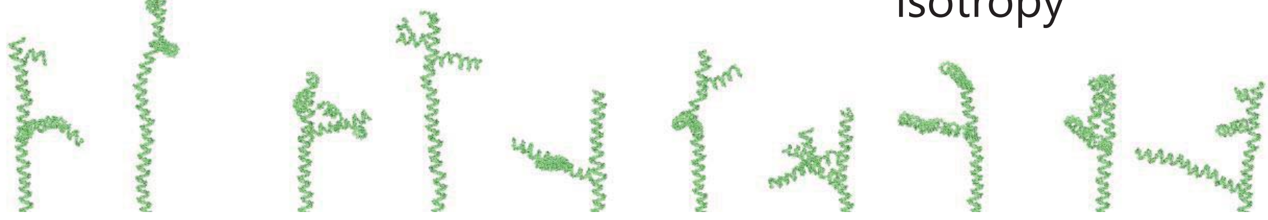
focus:
branch lengthes,
…

Polymerization Example

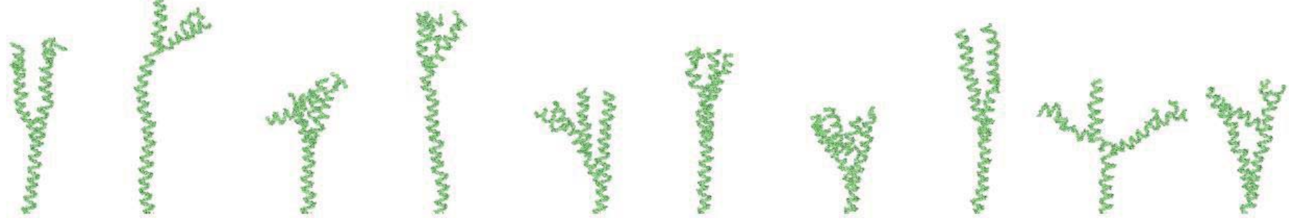
Context:

– ensembles of possible polymers

focus:
isotropy



focus:
lengthes, branching



Conclusions and Open Questions

New mappings can give new insight

– still interesting in visualization research! :–)

Scientific data is getting increasingly information-rich

– giving space to this additional data can pay off

How to combine spatial and non-spatial data vis. beyond

– juxtaposition and superposition
– explicit difference visualization

Acknowledgements

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et al.