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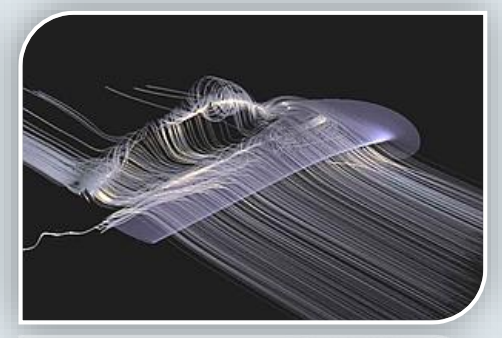
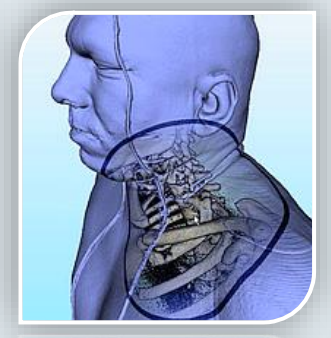


Visual Data Analytics
Data Representation

Dr. Johannes Kehrer – Siemens Technology, Munich

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Visualization Examples

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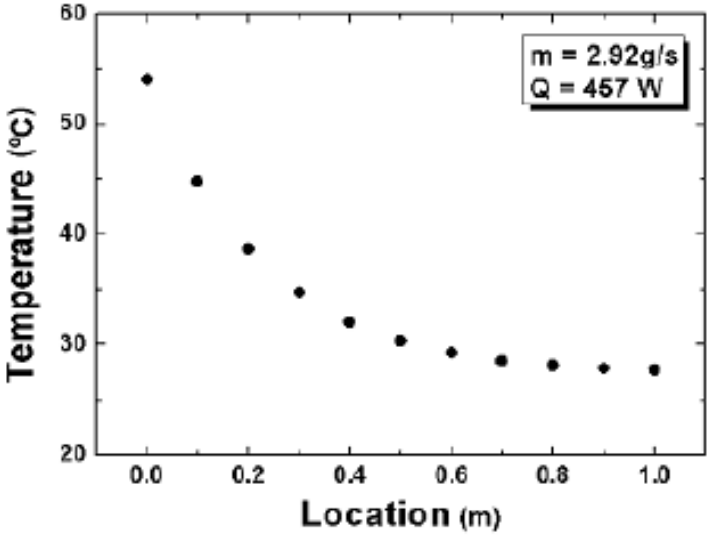

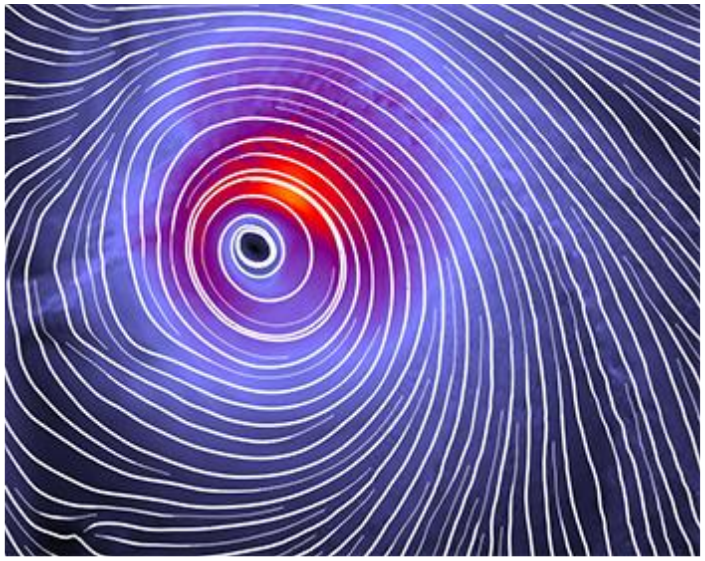

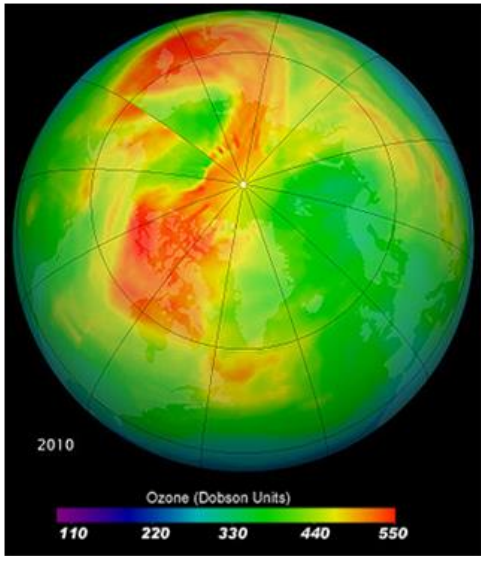

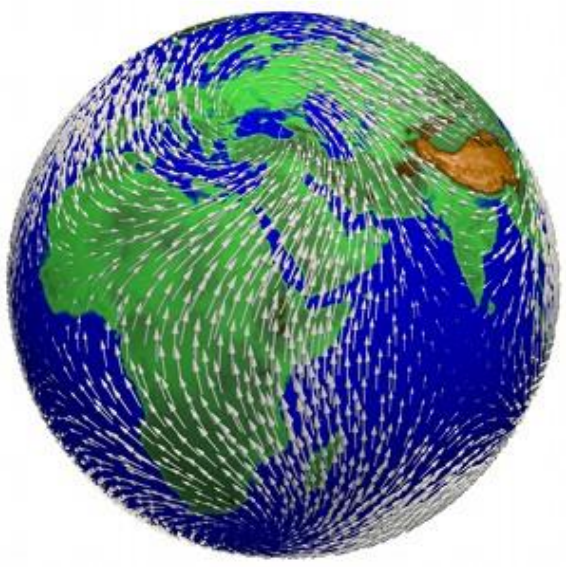

Data representation

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- Classification of visualization techniques according to
  - Dimension of the domain of the problem (independent variables)
  - Type and dimension of the data to be visualized (dependent variables)

Data representation

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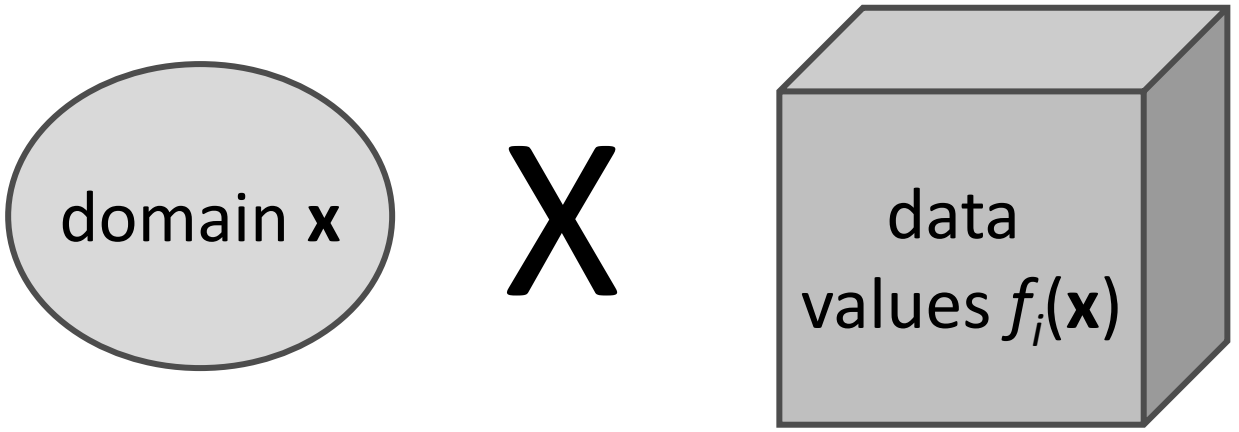
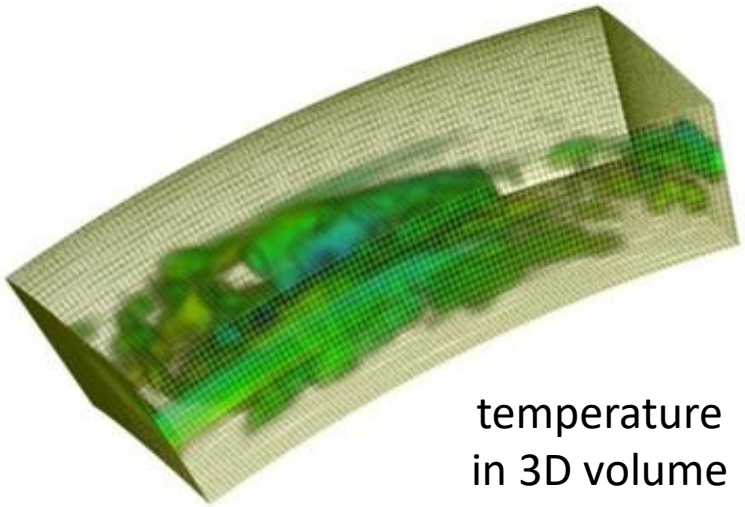
R^n R^m



independent variables
(e.g., 2D/3D space, time)

dependent variables
(e.g., temperature, density values, velocity vectors)



temperature
in 3D volume

scientific data $\subseteq R^{n+m}$

Data representation

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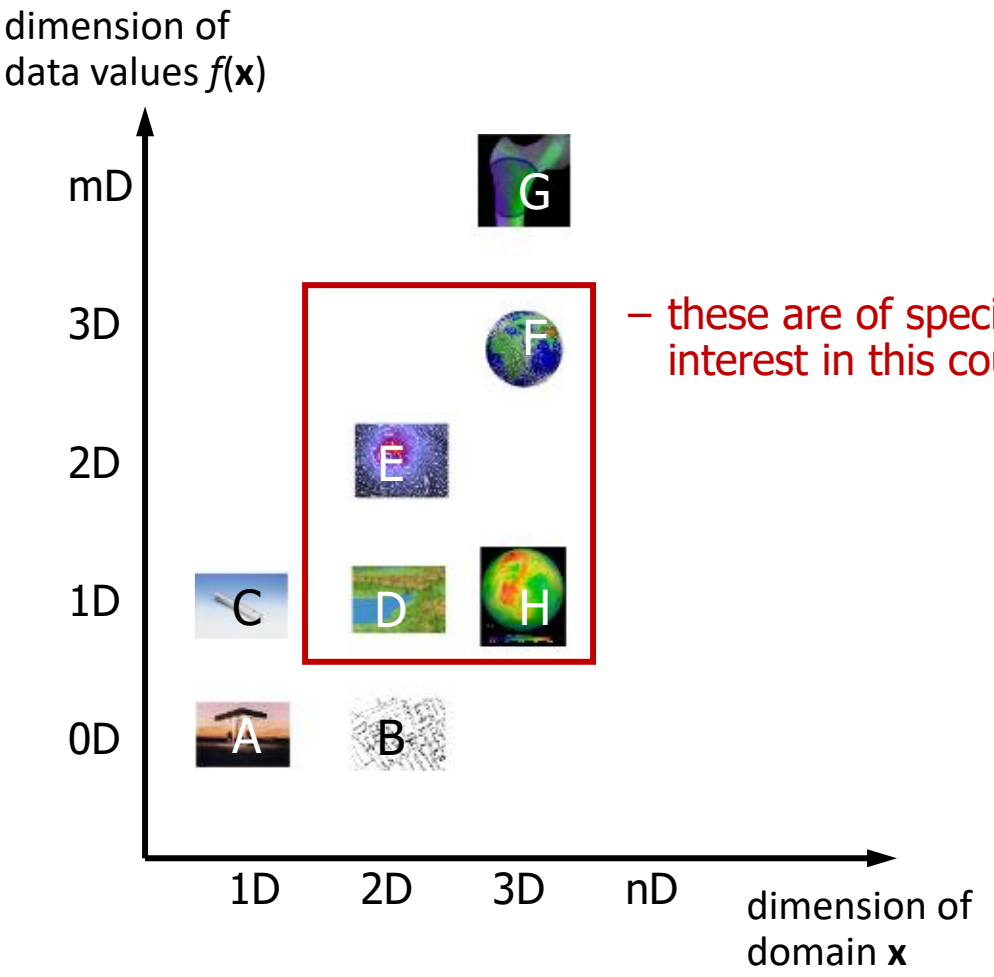

– these are of special interest in this course

Examples:

A: gas stations along a road
B: map of cholera in London
C: temperature along a rod
D: height field of a continent
E: 2D air flow
F: 3D air flow in the atmosphere
G: stress tensor in a joint
H: ozone concentration in the atmosphere

Data representation

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- Multidimensional data

Car name	MPG	Cylinders	Horse-power	Weight	Accel-eration	Model year	Origin
chevrolet woody	24,5	4	98	2164	22,1	1976	US
vw rabbit	29,0	4	90	1937	14,2	1976	Europe
honda civic	33,0	4	91	1795	17,4	1976	Japan
dodge aspen se	20,0	6	225	3651	17,7	1976	US
ford granada ghia	18,0	6	250	3574	21	1976	US
pontiac ventura sj	18,5	6	250	3645	16,2	1976	US
amc pacer d/l	17,5	6	258	3193	17,8	1976	US
volkswagen rabbit	29,5	4	97	1825	12,2	1976	Europe
datsun b-210	32,0	4	85	1990	17	1976	Japan
toyota corolla	28,0	4	97	2155	16,4	1976	Japan
ford pinto	26,5	4	140	2565	13,6	1976	US
volvo 245	20,0	4	130	3150	15,7	1976	Europe
plymouth volare premier v8	13,0	8	318	3940	13,2	1976	US
peugeot 504	19,0	4	120	3270	21,9	1976	Europe
toyota mark ii	19,0	6	156	2930	15,5	1976	Japan
mercedes-benz 280s	16,5	6	168	3820	16,7	1976	Europe
cadillac seville	16,5	8	350	4380	12,1	1976	US

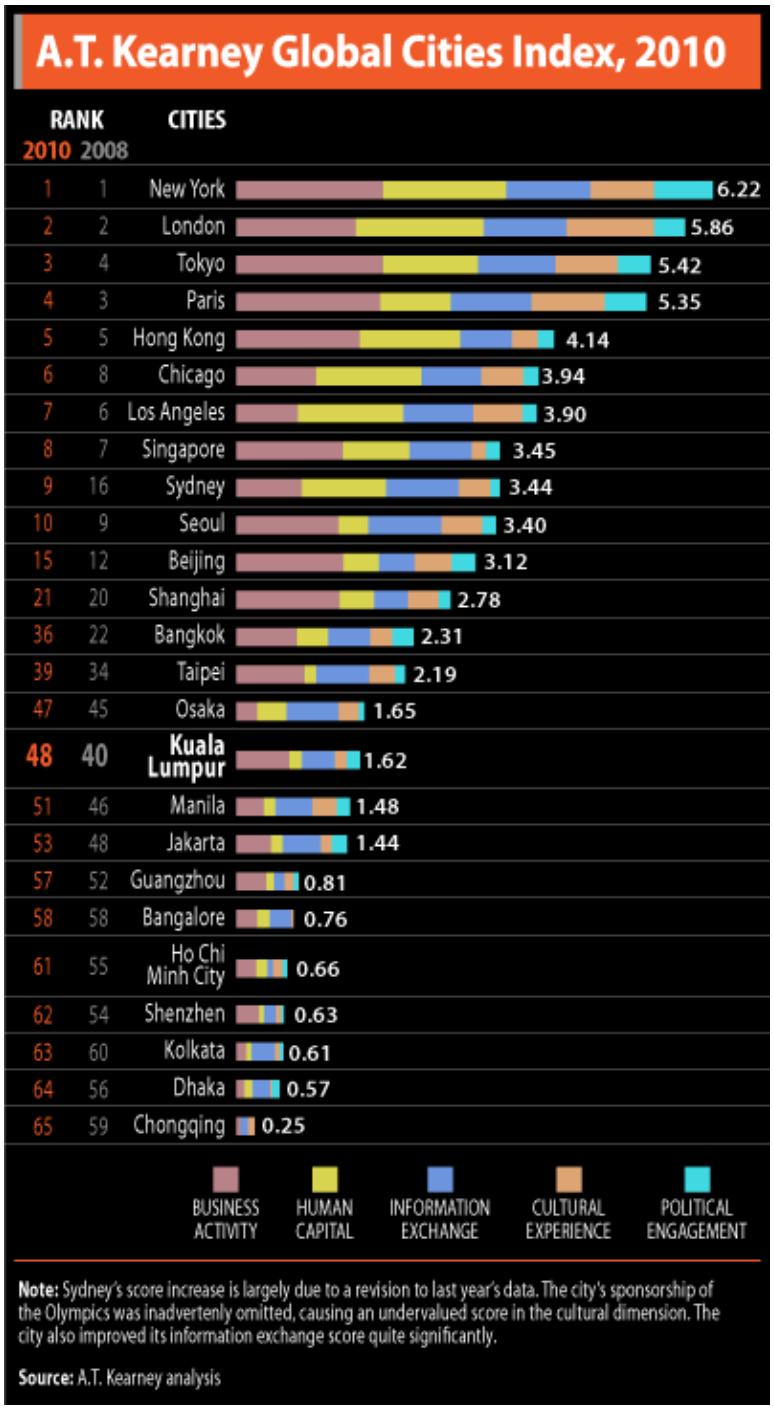
Attribute / Dimension

Record/Item

Data representation

- Multidimensional data

1	Vienna	108.6
2	**Zurich**	**108.0**
3	**Geneva**	**107.9**
4	Vancouver	107.4
4	Auckland	107.4
6	Dusseldorf	107.2
7	Frankfurt	107.0
7	Munich	107.0
9	**Bern**	**106.5**
10	Sydney	106.3
11	Copenhagen	106.2
13	Amsterdam	105.7
15	Brussels	105.4
17	Berlin	105.0
19	Luxembourg	104.6
26	Dublin	103.6
28	Singapore	103.5
34	Paris	102.9
39	London	101.6
40	Tokyo	101.4
49	New York City	100.0



Data representation

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- Characteristics of data values
  - Attribute types (quantitative vs. qualitative)
  - Domain (continuous vs. discrete)
  - Value range (includes precision of values)
  - Data type (categorical, scalar, vector, tensor data)
  - Dimension (number of components)
  - Error and uncertainty
  - (physical) interpretation

Attribute types

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- Quantitative (numerical, measurable)
  - Objective data produced through a systematic process, not subject to interpretation (e.g., length, mass, temperature)
  - Metric scale – allows measure of distance
  - Continuous (real) or discrete (distinct & separate values)

- Qualitative (categorical data, not measurable)
  - No metric scale; cannot be measured
  - Requires a subjective decision in order to be categorized
  - Discrete

Attribute types

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- Qualitative (categorical data)
  - Nominal  
    - No natural ordering or indication of values, only equivalence and membership ($=, \neq$)
    - Eye color (blue, green, brown)
  - Ordinal  
    - Logical order relation ($<, >$), but no relative size or degree of difference
    - Judgment of size (small, medium, large, etc.)
    - Attitudes (strongly disagree, disagree, neutral, agree, strongly agree)
    - Living quality (very high, high, medium, low, very low)

Attribute types

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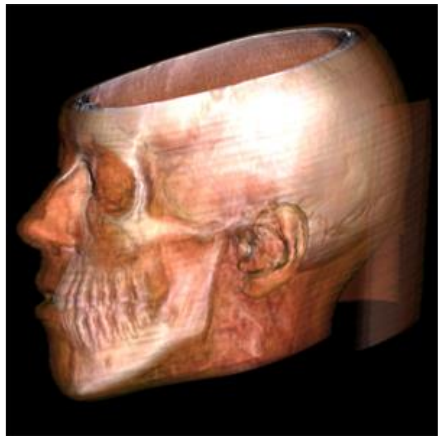
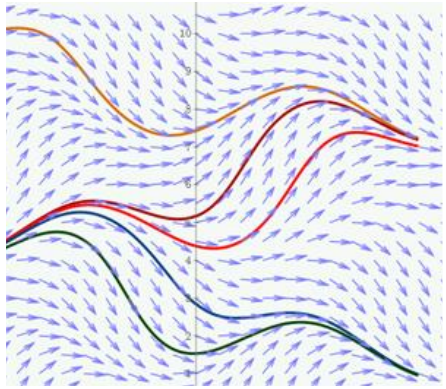
- Categorical data
  - Values from a fixed number of categories
- Scalar data
  - Given by a function $f(x_1,\ldots,x_n)$: $\mathbb{R}^n \rightarrow \mathbb{R}$ with n independent variables x_i
- Vector data
  - Represent direction and magnitude and given by an n-tupel $(f_1, \ldots, f_n)$ with $f_k = f_k(x_1, \ldots, x_n)$
  - 2D vector field where every sample represents a 2D vector (u, v) with $u = f(x, y)$ and $v = g(x, y)$
- Tensor data
  - A multi-dimensional matrix





Data representation

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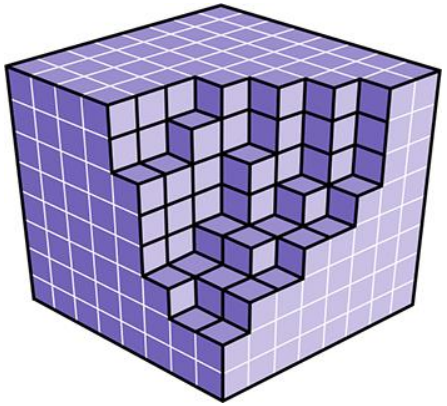
- In many cases, the visualization data represent a continuous real object
  - e.g., oscillating membrane, velocity field around a body, human organ or tissue, etc.
  - This object lives in an *n*-dimensional space - the domain

- Usually, the data is only given at a finite set of locations in space and/or time
  - Think of measurement devices & numerical simulations (note similarity to pixel images)



- We call this a discrete representation of a continuous object

Scientific Visualization

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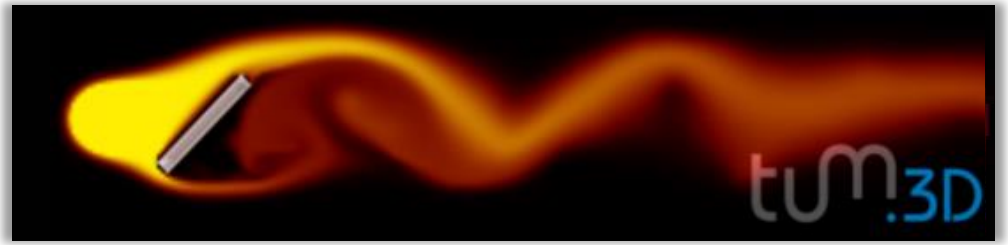
- Deals with the reconstruction of a continuous real object from a given discrete representation
- Data that has some physical or geometric correspondence



Information Visualization / Visual Analytics

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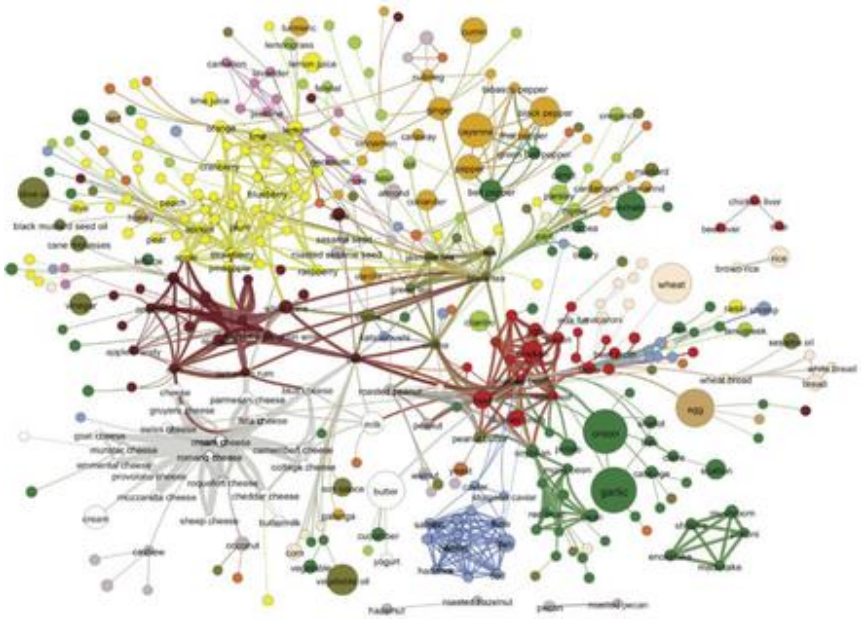
- Deal with data that is discrete and more abstract
  - Does not have a physical or geometric correspondence
  - Symbolic, tabular, networked, graphs, textual information



Flavor compounds shared by culinary ingredients

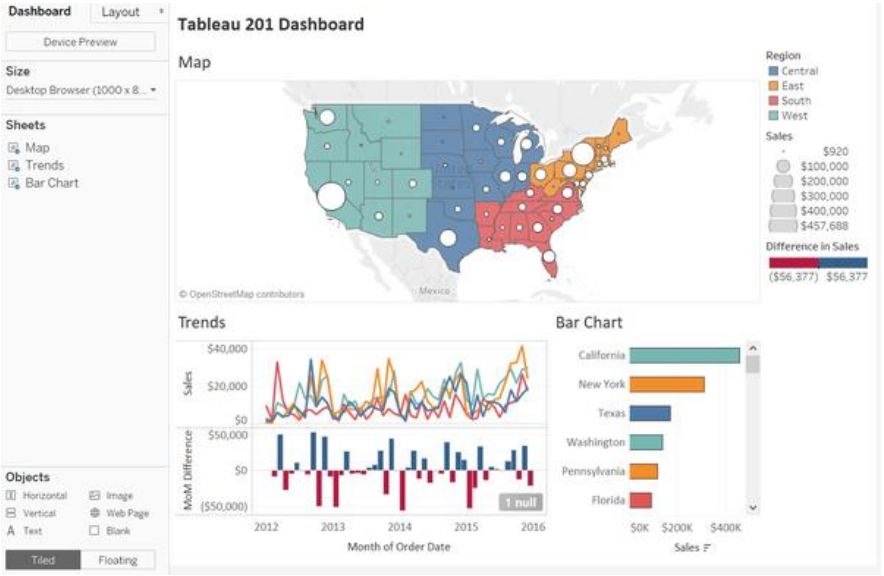


Tableau Software

Visualization – Major Areas

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- Volume Visualization
- Flow Visualization

} Scientific Visualization

Inherent spatial reference

3D

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nD

- Information Visualization
- Visual Analytics

Usually no spatial reference

Data representation

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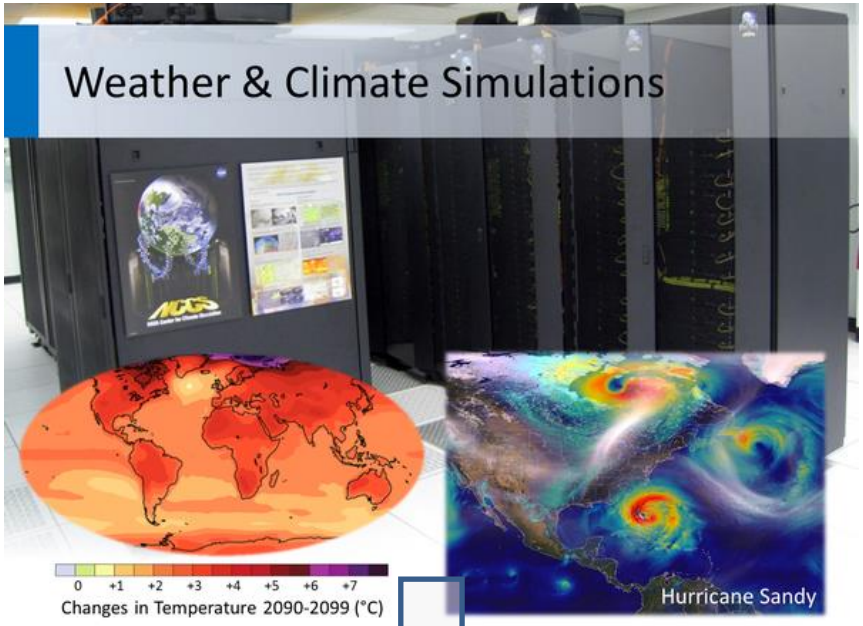

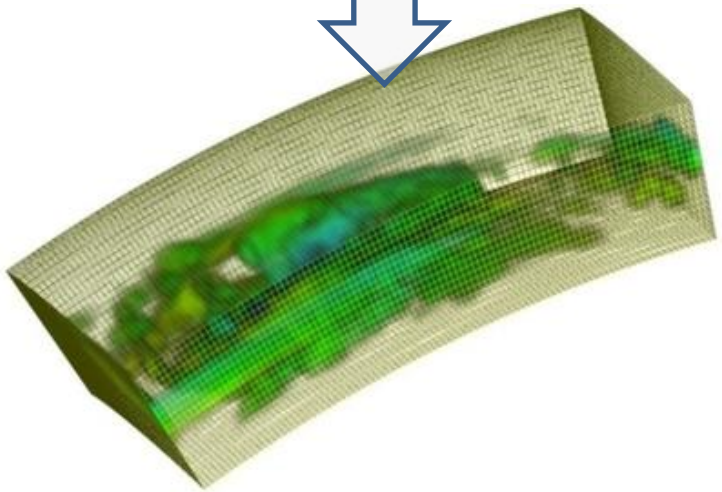

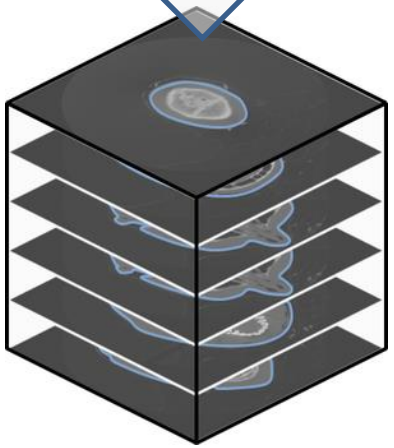

Data representation

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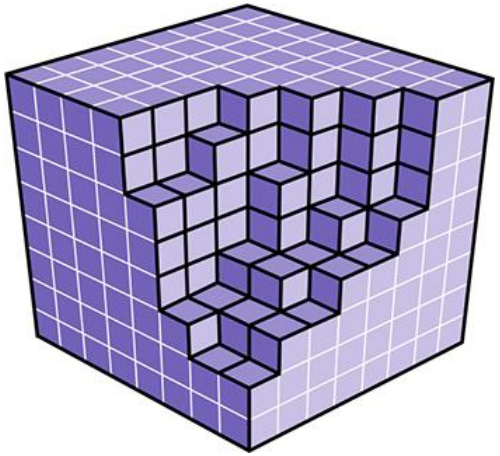
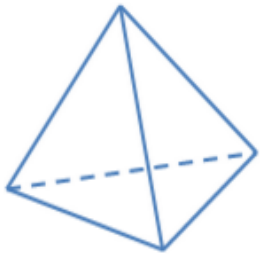
- Discrete representations
  - Data samples (values) typically given on meshes/grids consisting of cells
  - Compact/efficient data representation

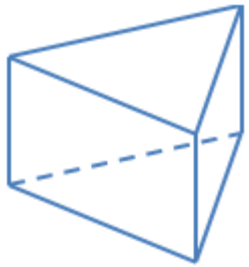


Primitives in different dimensions

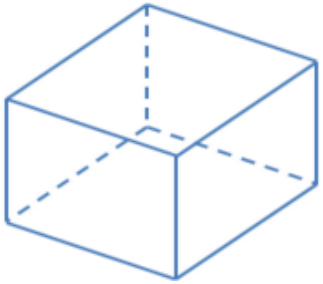
dimension	cell	mesh
0D	points	
1D	lines (edges)	polyline
2D	triangles, quadrilaterals (rectangles)	2D mesh
3D	tetrahedra, prisms, hexahedra	3D mesh or grid



Tetrahedron



Prism



Hexahedron

Data representation

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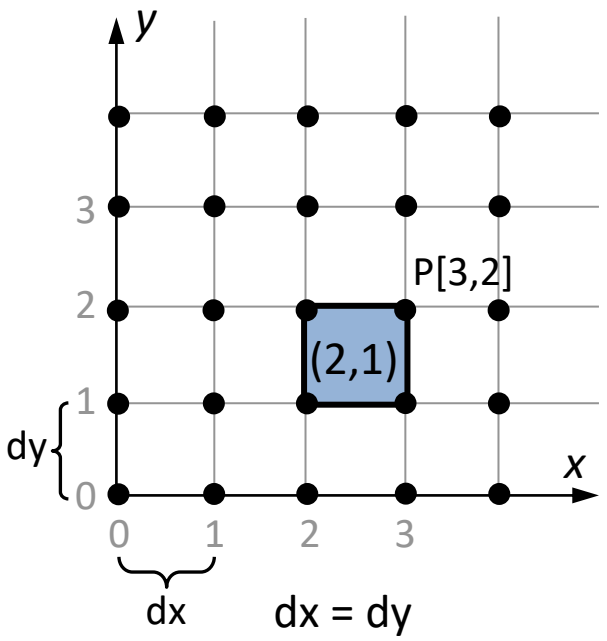
- Grids: Cartesian or equidistant grid
  - Samples at equidistant intervals along Cartesian coordinate axes
  - Neighboring samples are connected via edges
  - Cells formed by 4 (2D) or 8 (3D) samples
  - Cells and samples (grid vertices) are numbered sequentially with respect to increasing coordinates



Data representation

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- Some properties of Cartesian grids
  - Assuming N_x and N_y vertices along *x*- and *y*-axis
  - Number of vertices = $N_x \cdot N_y$
  - Number of cells = $(N_x - 1) \cdot (N_y - 1)$
  - Vertex positions are given implicitly from indices [*i*,*j*]:
    - P[*i*,*j*].x = origin + $i \cdot$ dx
    - P[*i*,*j*].y = origin + $j \cdot$ dy
  - It is a structured grid
    - Neighboring information (topology) is given implicitly
    - Neighbors obtained by incrementing/decrementing indices

Data representation

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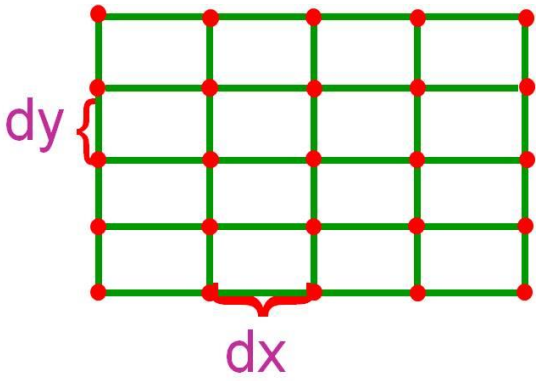
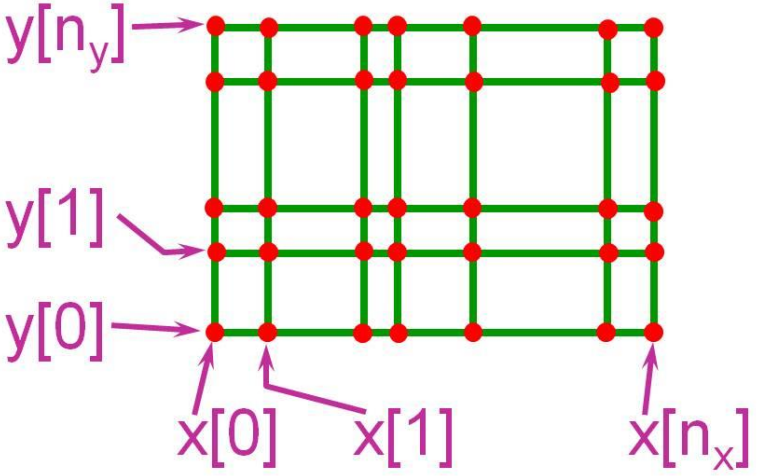
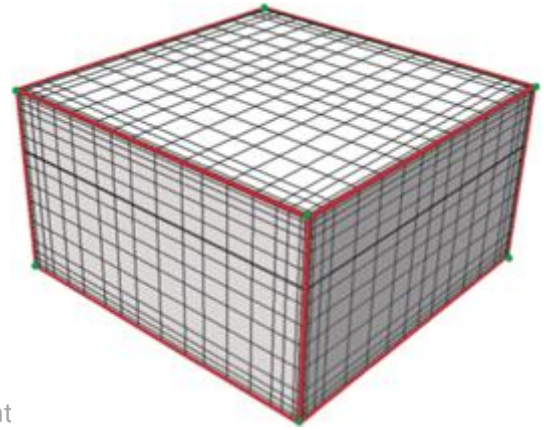
- Uniform or Regular Grid
  - Orthogonal, equidistant grid
  - dx ≠ dy



- Rectilinear Grid
  - Varying sample-distances x[i], y[j]





Gröller & Hauser / Telea

Data representation

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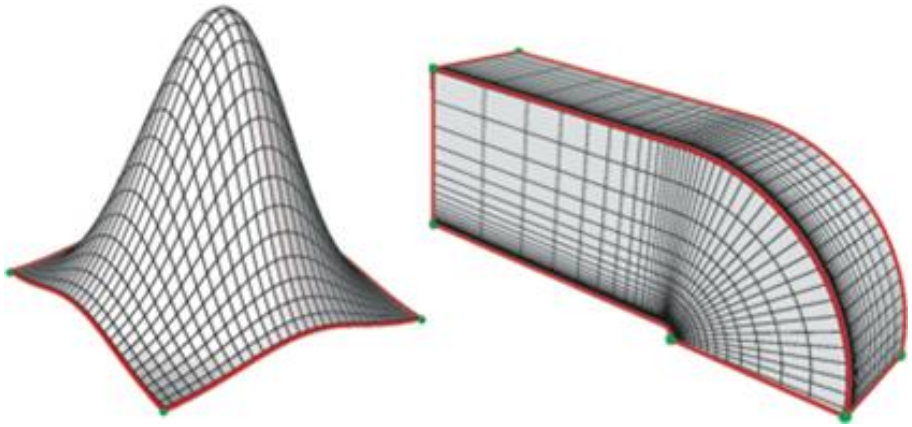
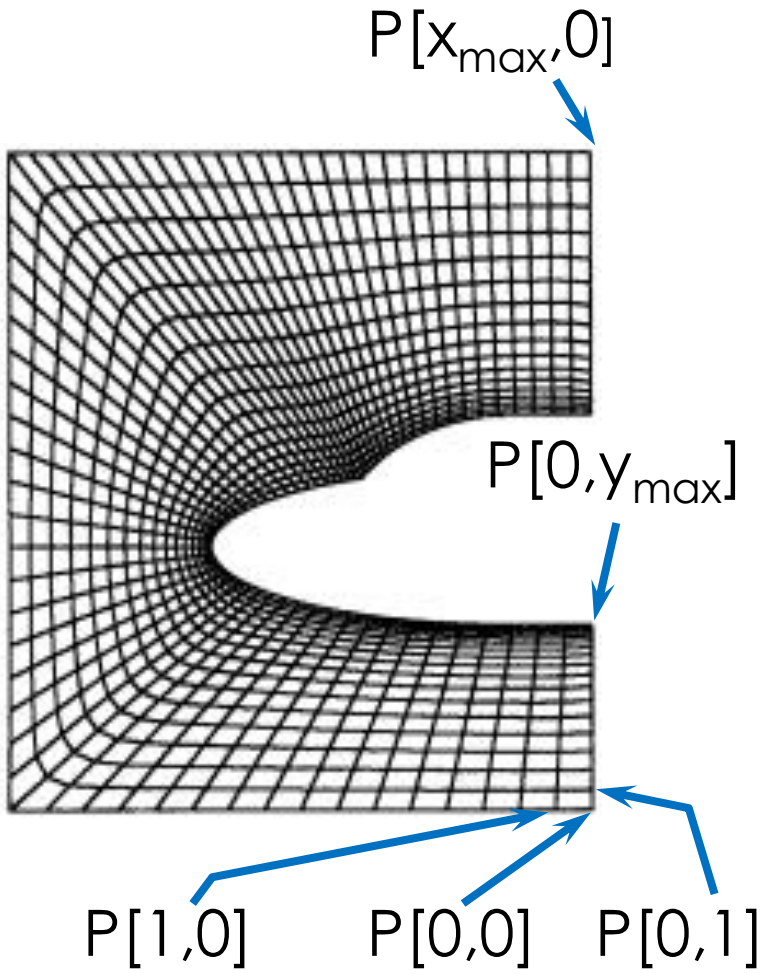
- Curvilinear Grid
  - Non-orthogonal grid
  - Grid-points specified explicitly (P[i,j])
  - Implicit neighborhood relationship





Data representation

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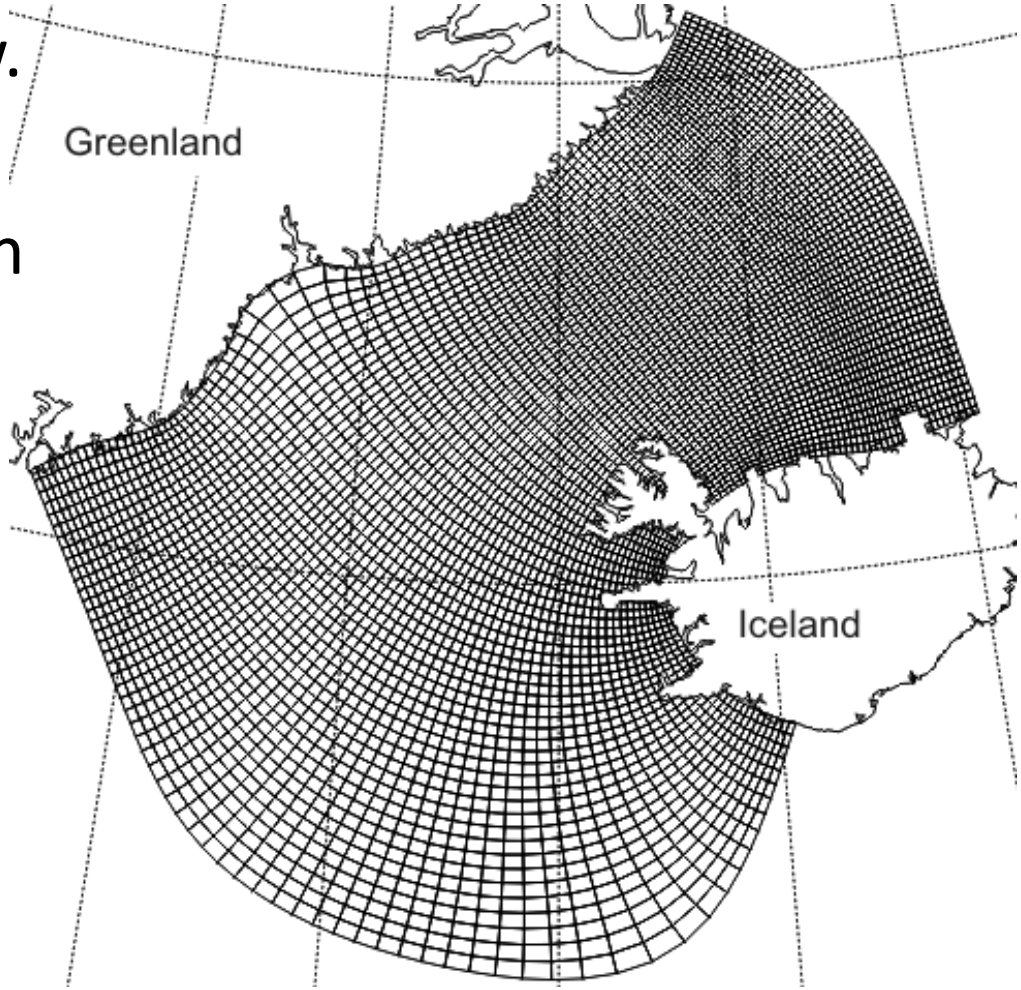
- Curvilinear Grid
  - Example: Region betw. Greenland & Iceland
  - Grid spacings between 5 and 40 km



Data representation

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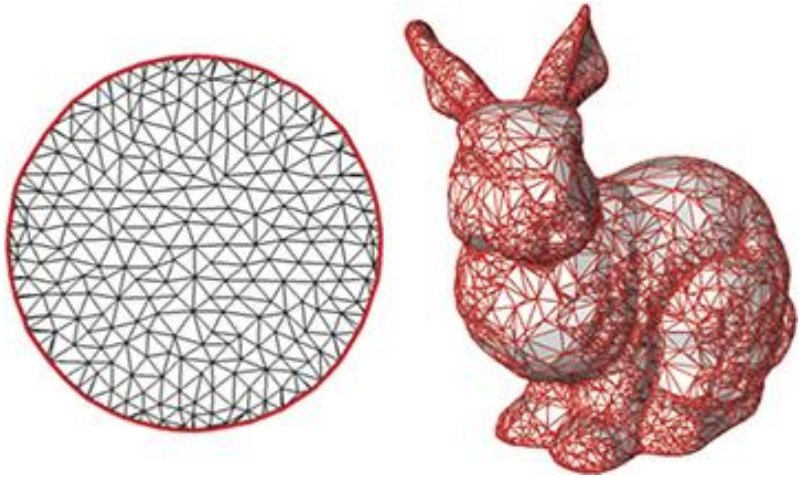
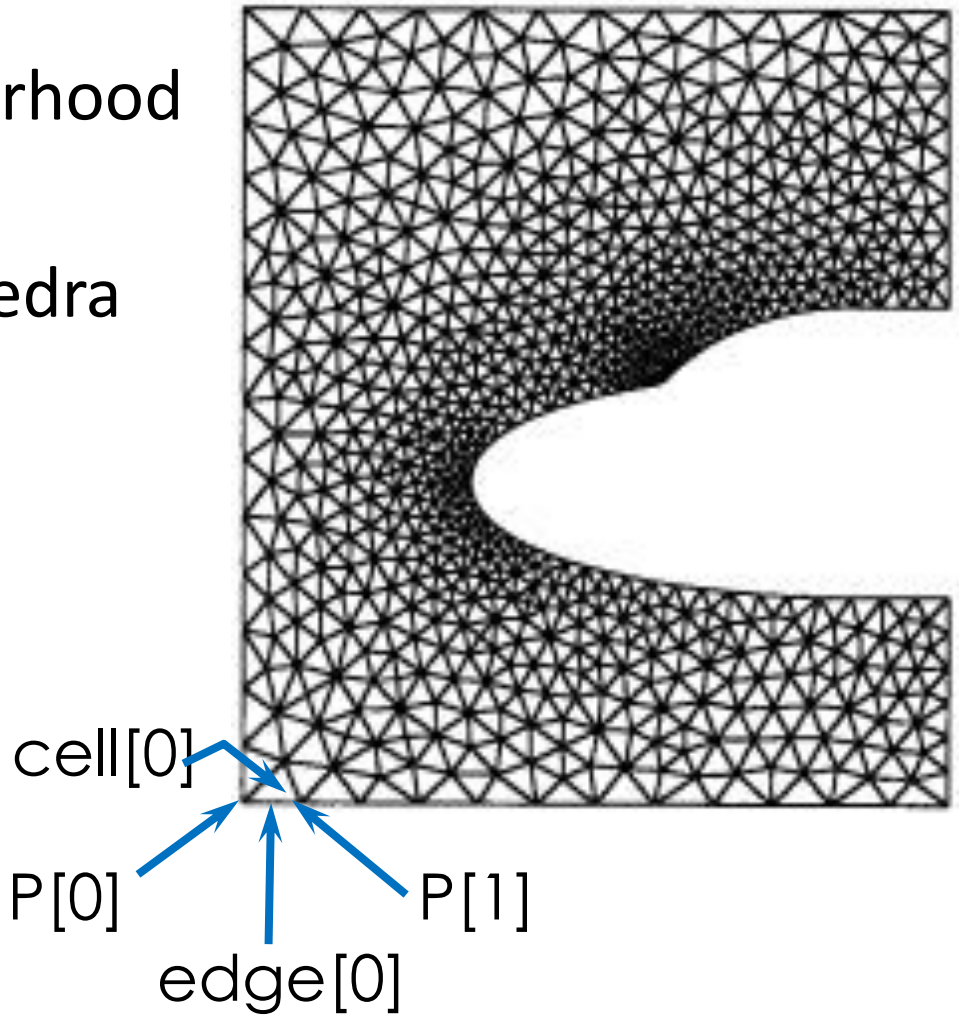
- Unstructured grid
  - Grid points and neighborhood specified explicitly
  - Cells: tetrahedra, hexahedra





Data representation

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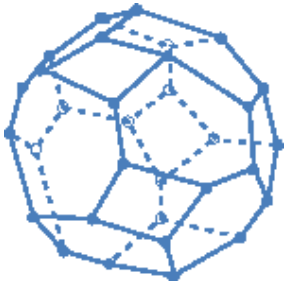
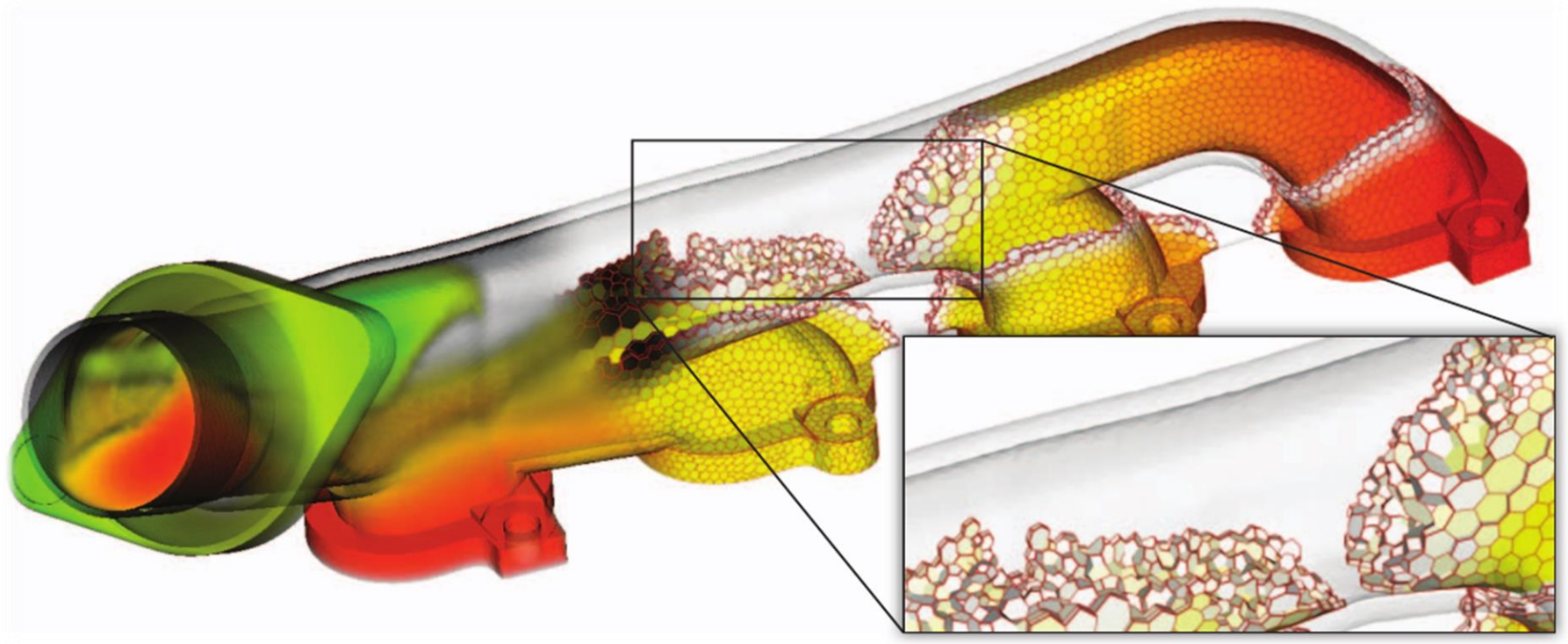
- Unstructured grid
  - Example: Exhaust Manifold with general (non-convex) polyhedra





Muigg et al. 2011

Data representation

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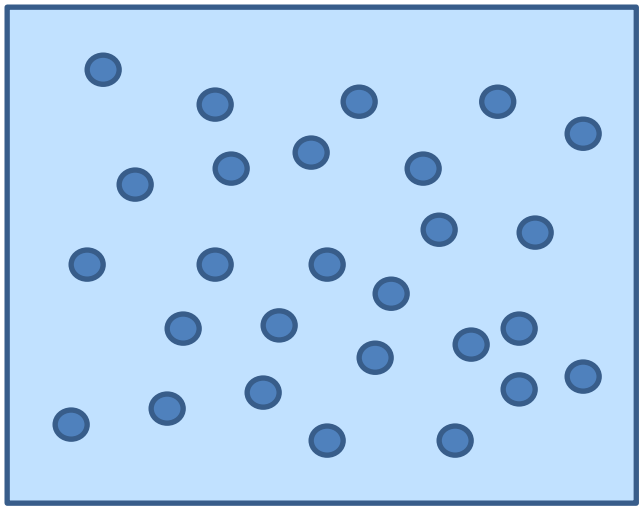
- Scattered Data
  - Grid-free data
  - Data points given without neighborhood-relationship
  - Influence on neighborhood defined by spatial proximity
  - Scattered data interpolation



Contact information

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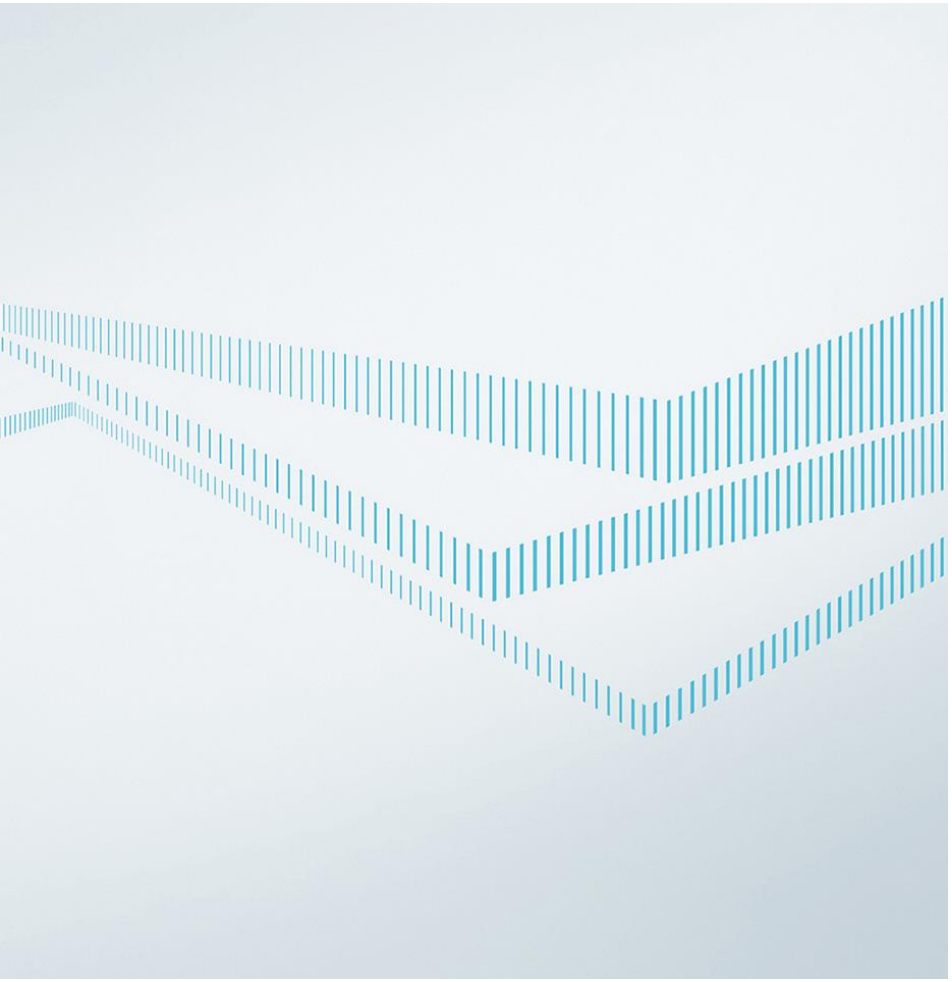

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