Visualization – lecture unit #2

on data, grids, …

Retrospection: lecture unit #1

- Visualization lab: organizational details
- Content of 1. lecture unit
  - Visualization - Definition
  - Application examples
  - Visualization for: exploration, analysis, presentation
  - Scientific Visualization vs. Information Visualization
  - Visualization pipeline

Overview: lecture unit #2

- Content of 2. lecture unit:
  - Visualization scenarios
  - On Data
  - Visualization examples
  - On grids
  - Visualization and color

Visualization Scenarios

How closely is visualization connected to the data generation?

- Coupling varies considerably:
  - Data generation (data acquisition):
    - Measuring, Simulation, Modelling
    - Can take very long (measuring, simulation)
    - Can be very costly (simulation, modelling)
  - Visualization (rest of visualization pipeline):
    - Data enhancement, vis. mapping, rendering
    - Depending on computer, implementation: fast or slow
  - Interaction (user feedback):
    - How can the user intervene, vary parameters

Passive Visualization (min.)

- All three steps separated:
  - **Data generation**
    - Measurements
    - Simulation
    - Modelling
  - **Off-line Visualization**:
    - Previously generated data are visualized
    - Result: video or images/animation
  - **Passive Visualization**:
    - Viewing of the visualization results

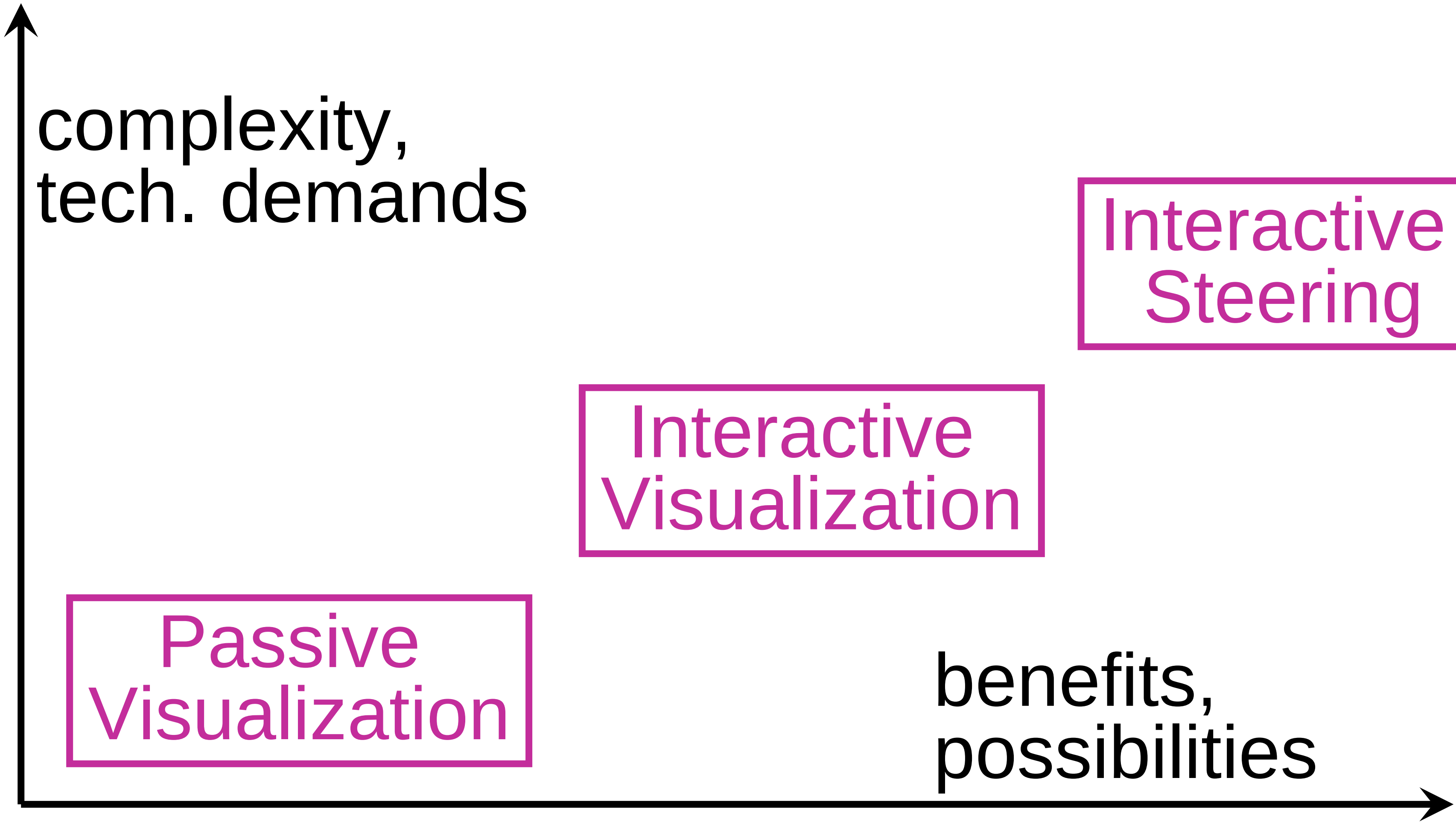
Interactive Visualization (med.)

- Only data generation is separated:
  - **Off-line data generation**:
    - Measurments, Simulation, Modelling
  - **Interactive Visualization**:
    - Previously generated data are available
    - Visualization program allows interactive visualization of the data
    - Possibilities:
      choice, variation, parameterization of the visualization technique
    - Nowadays widespread

Interactive Steering (max.)

- All three steps coupled:
  - **Interactive Steering**:
    - Simulation and/or modelling (measuring) generate data “on the fly”
    - Interactive visualization allows “real-time” insight into the data
    - Extended possibilities:
      user can interfere with the simulation and/or the modelling, change the design, aso.
    - Often requires lots of efforts, very costly

Visualization Scenarios



On Data

Data characteristics,
Data attributes,
Data spaces

Data – General Information

- Data:
  - Focus of visualization,
    everything is centered around the data
  - Driving factor (besides user) in choice and attribution of the visualization technique
  - Important questions:
    - Where do the data "live" (**data space**)
    - **Type** of the data
    - Which **representation** makes sense (secondary aspect)

Data Space

- Where do the data "live"?
  - inherent spatial domain (**SciVis**):
    - 2D/3D data space given
    - Examples: medical data, flow simulation data, GIS-data, etc.
  - no inherent spatial reference (**InfoVis**):
    - Abstract data,
      spatial embedding through visualization
    - Example: data bases
  - **Aspects**: dimensionality (data space), coordinates, region of influence (local, global), domain

Data Characteristics

- What type of data?
  - **Data types**:
    - Scalar = numerical value (natural, whole, rational, real, complex numbers)
    - Non numerical (nominal, ordinal values)
    - Multidimensional values (n-dim. vectors, n×n-dim. tensors of data from same type)
    - multimodal values (vectors of data with varying type [e.g., row in a table])
  - **Aspects**: dimensionality, co-domain (range)

Data Representation

- How can data be represented?
  - inherent spatial domain?
    - Yes $\Rightarrow$ Recycle data space? Or not?
    - No $\Rightarrow$ Select which representation space?
  - Which dimension is used what for?
    - Relationship data space $\Leftrightarrow$ data characteristics
    - Available display space (2D/3D)
    - Where is the focus?
    - Where can you abstract / save (e.g., too many dimensions)

Data Space vs. Data characteristics

	1D	2D	3D
1D	y=f(x)		Spatial Curve **x**(t)
2D		2D-Flow **v**(**x**)	
3D	CT-data d(**x**)		

Examples

Visualization Examples

data	description	visualization example
$N^1 \rightarrow R^1$	value series	bar chart, pie chart, etc.
$R^1 \rightarrow R^1$	function	(line) graph
$R^2 \rightarrow R^1$	function over R^2	2D-height map in 3D, contour lines in 2D, false color map
$N^2 \rightarrow R^2$	2D-vector field	hedgehog plot, LIC, streamlets, etc.
$R^3 \rightarrow R^1$	3D-densities	iso-surfaces in 3D, volume rendering
$(N^1 \rightarrow)R^n$	set of tuples	parallel coordinates, glyphs, icons, etc.

Visualization Examples

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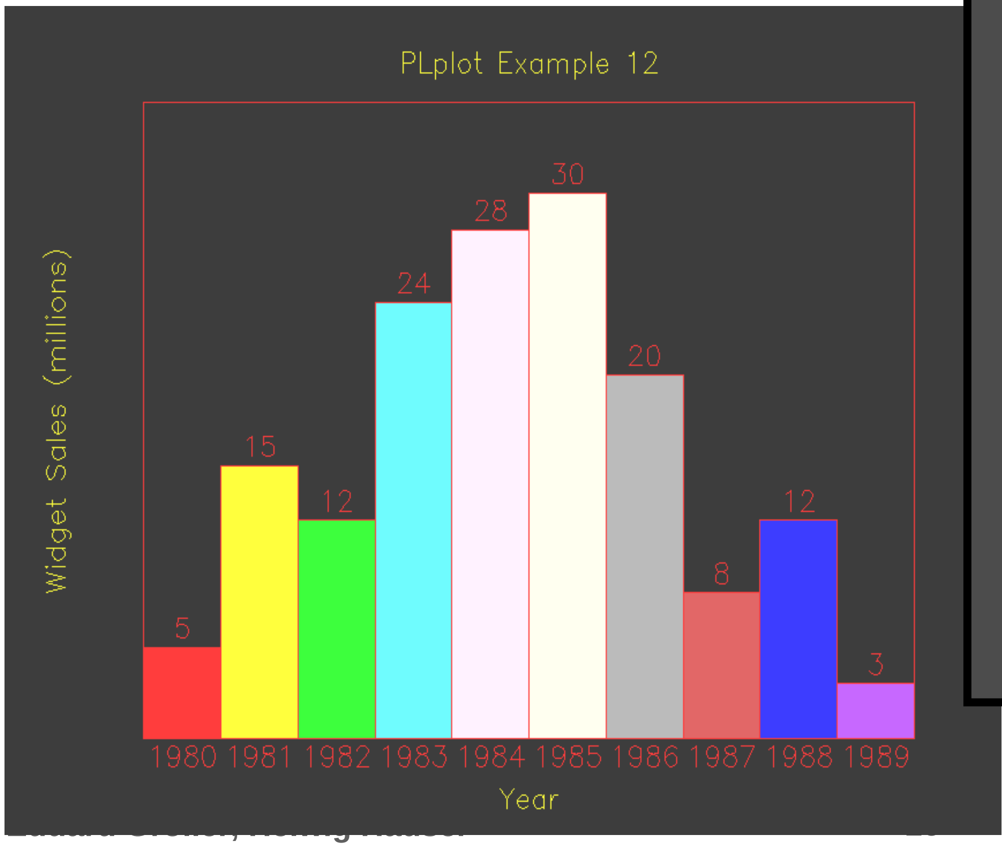
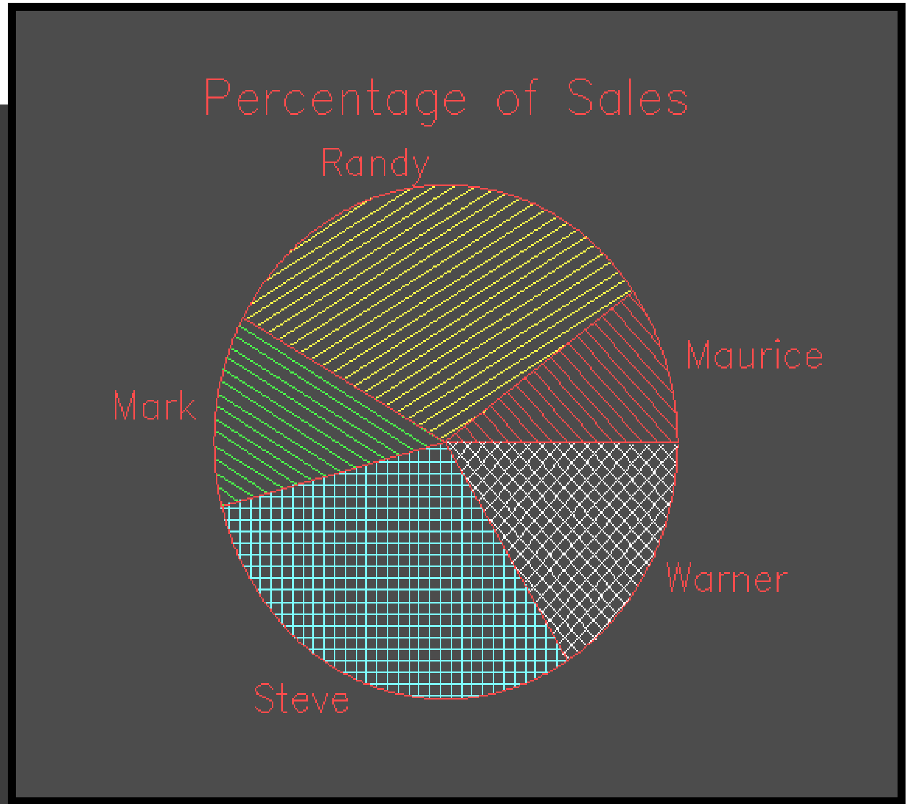
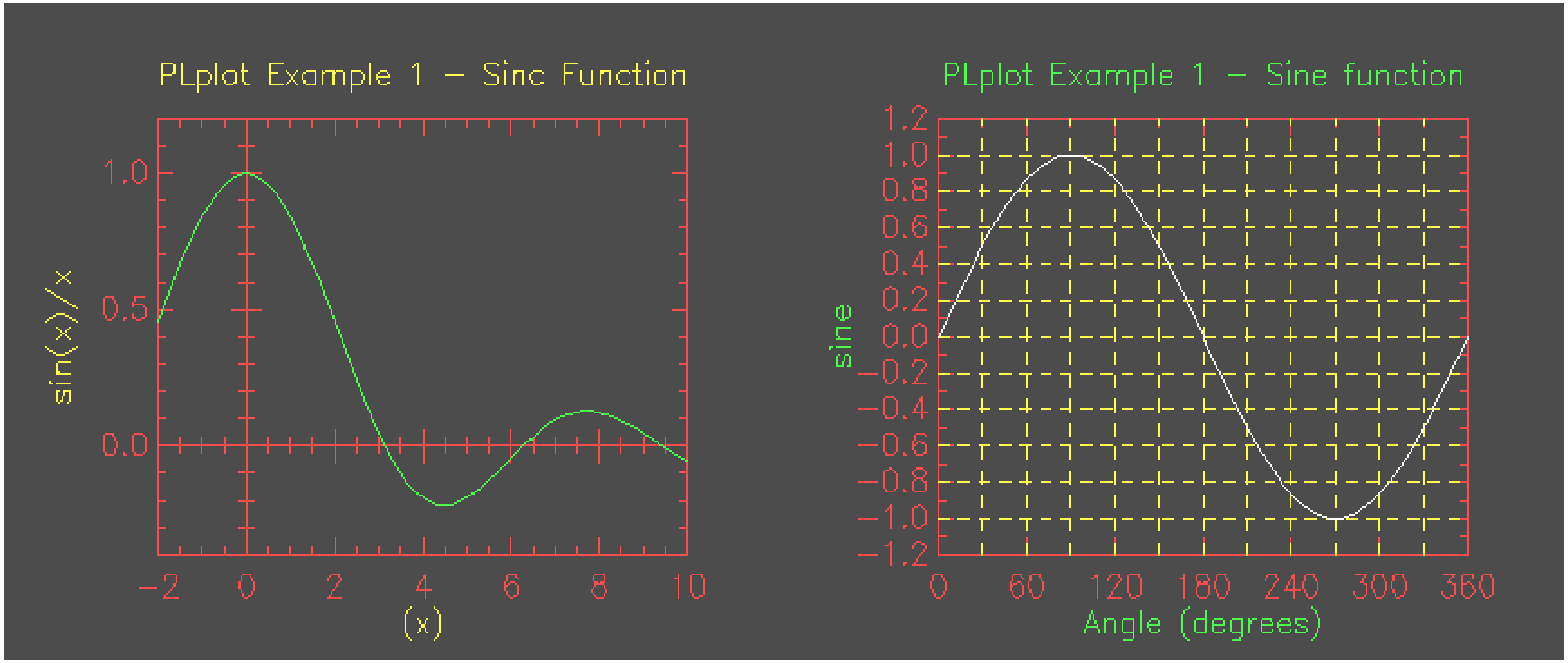
$N^1 \rightarrow R^1$	value series	bar chart, pie chart, etc.





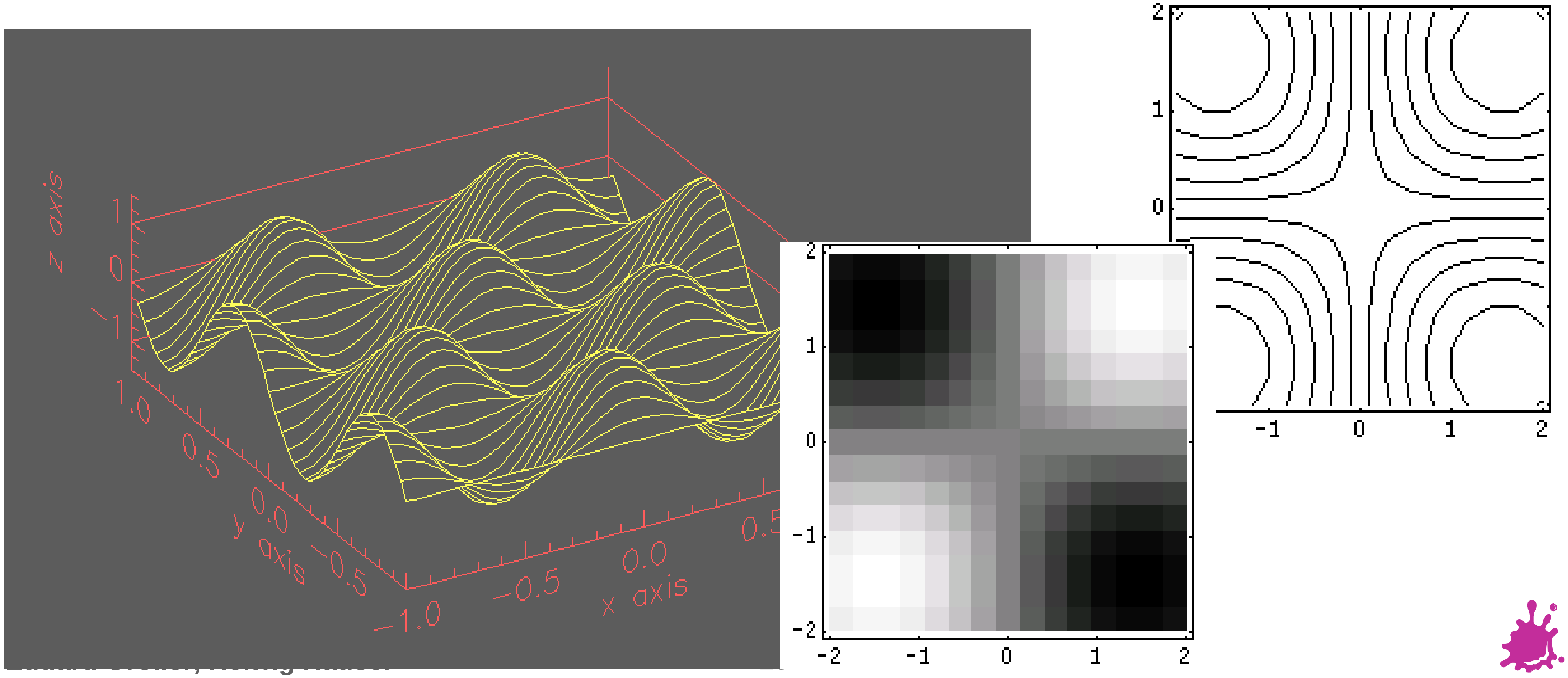
Visualization Examples

data	description	visualization example
$R^1 \rightarrow R^1$	function	(line) graph



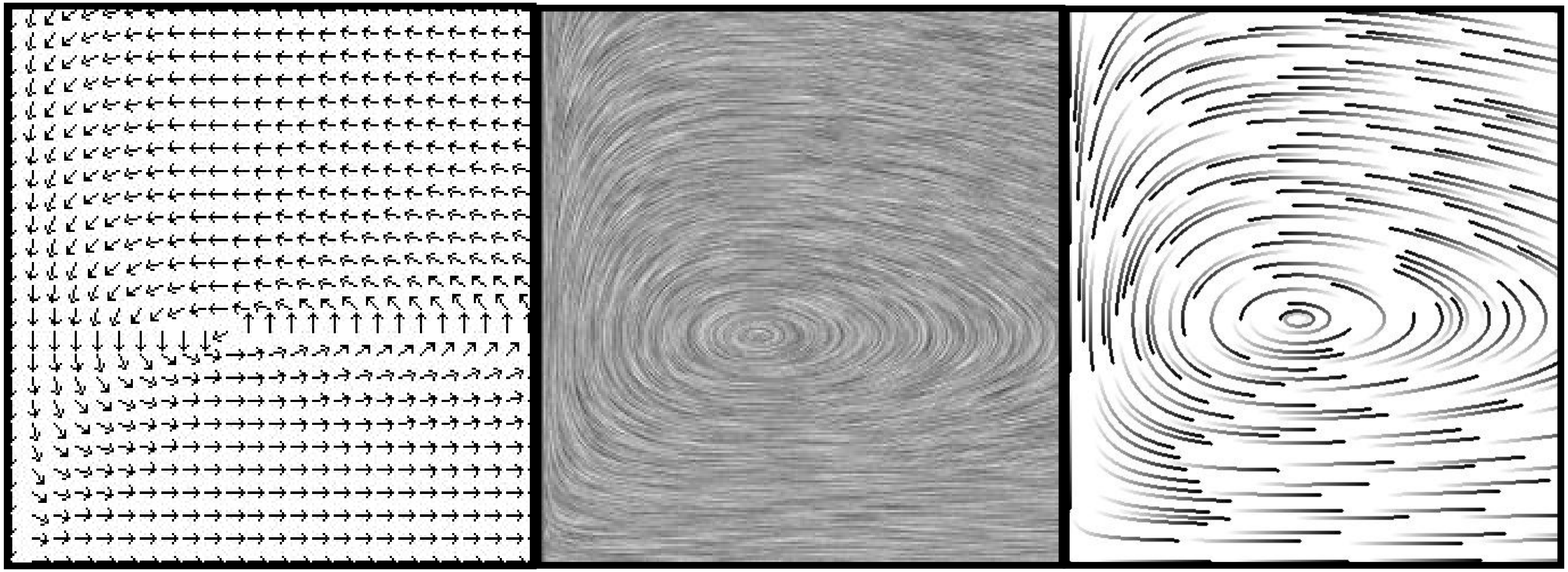
Visualization Examples

data	description	visualization example
$R^2 \rightarrow R^1$	function over R^2	2D-height map in 3D, contour lines in 2D, false color map



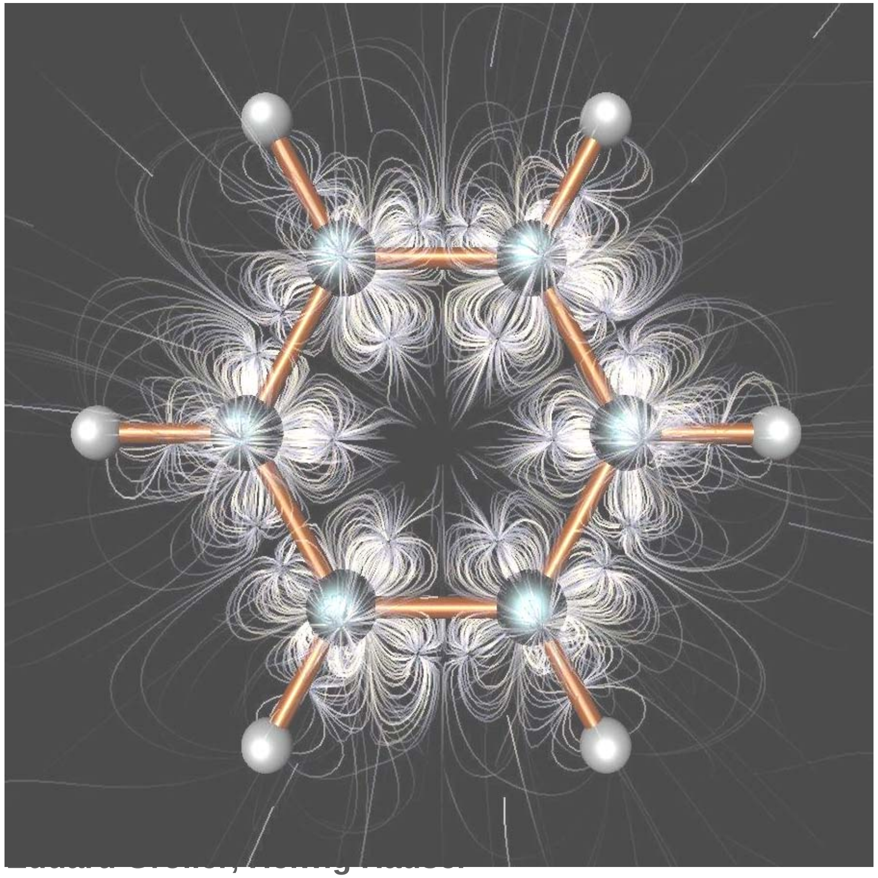
Visualization Examples

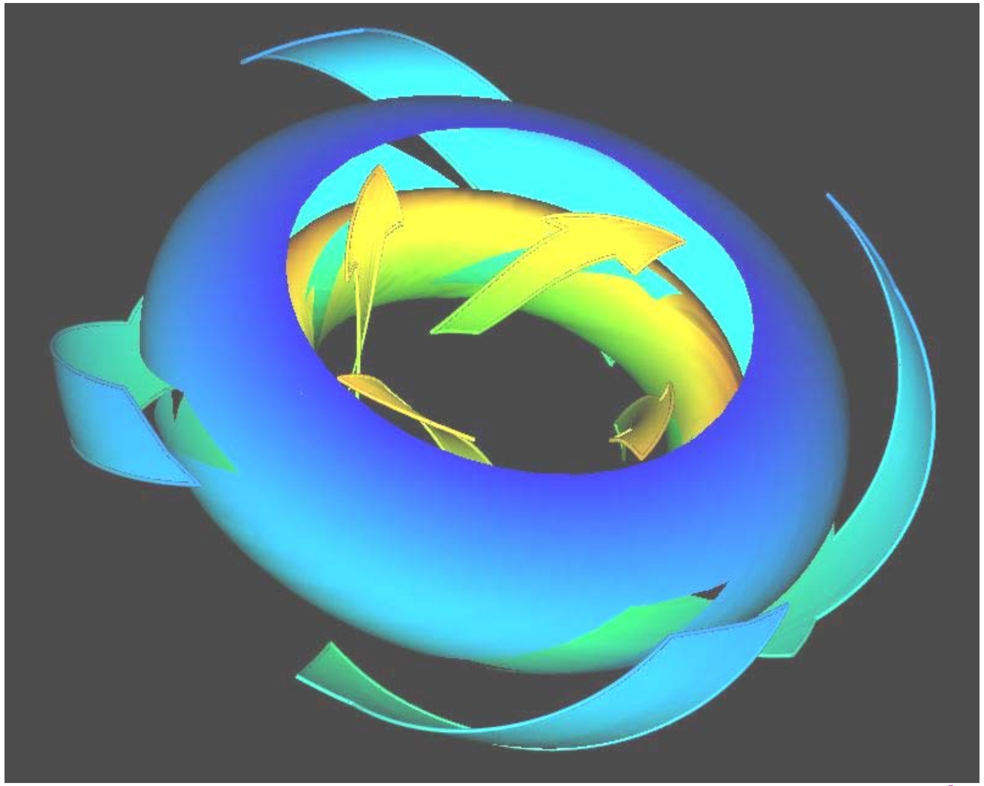
data	description	visualization example
$N^2 \rightarrow R^2$	2D-vector field	hedgehog plot, LIC, streamlets, etc



Visualization Examples

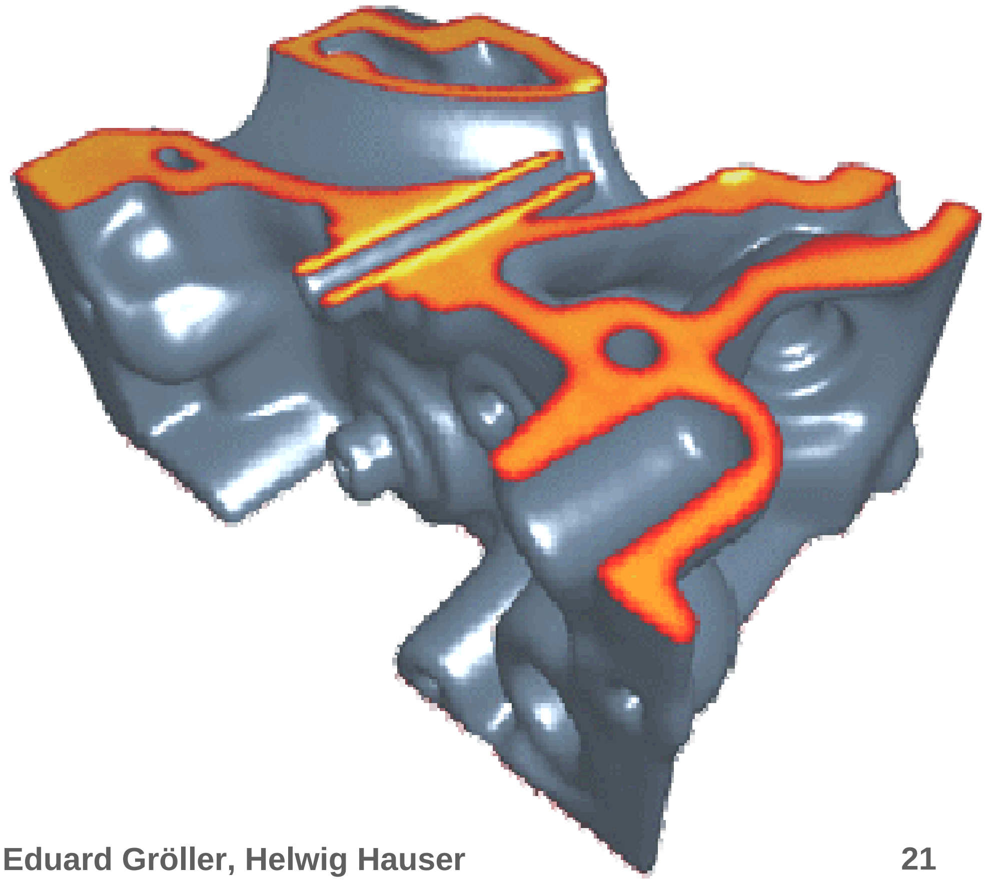
data	description	visualization example
$R^3 \rightarrow R^3$	3D-flow	streamlines, streamsurfaces

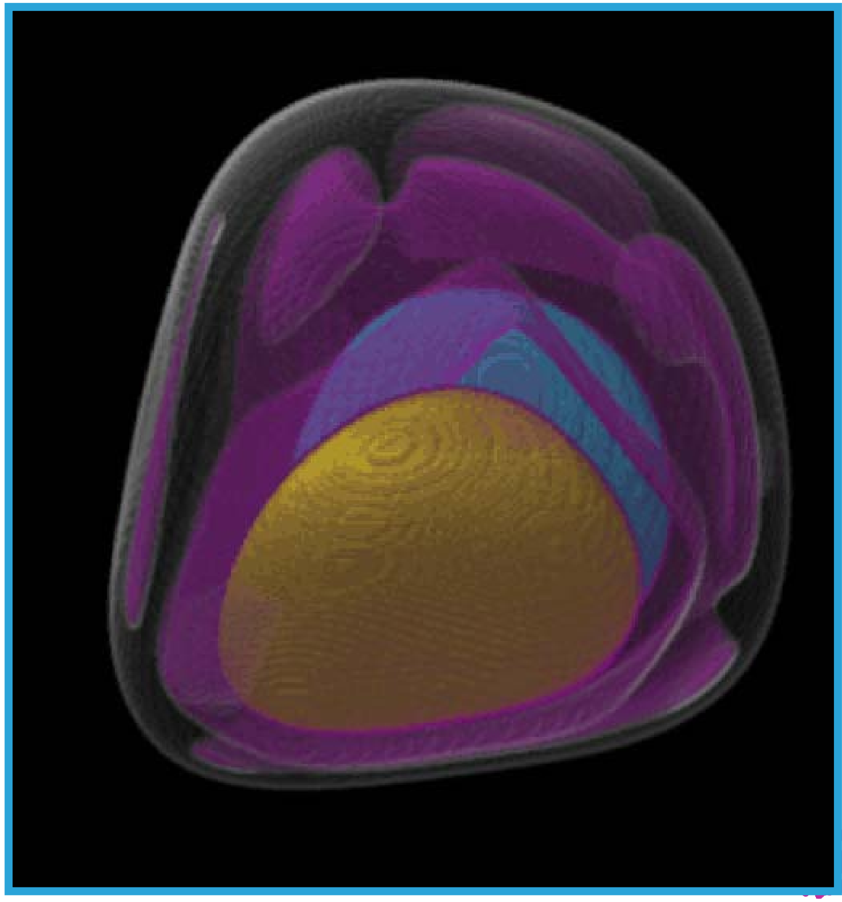




Visualization Examples

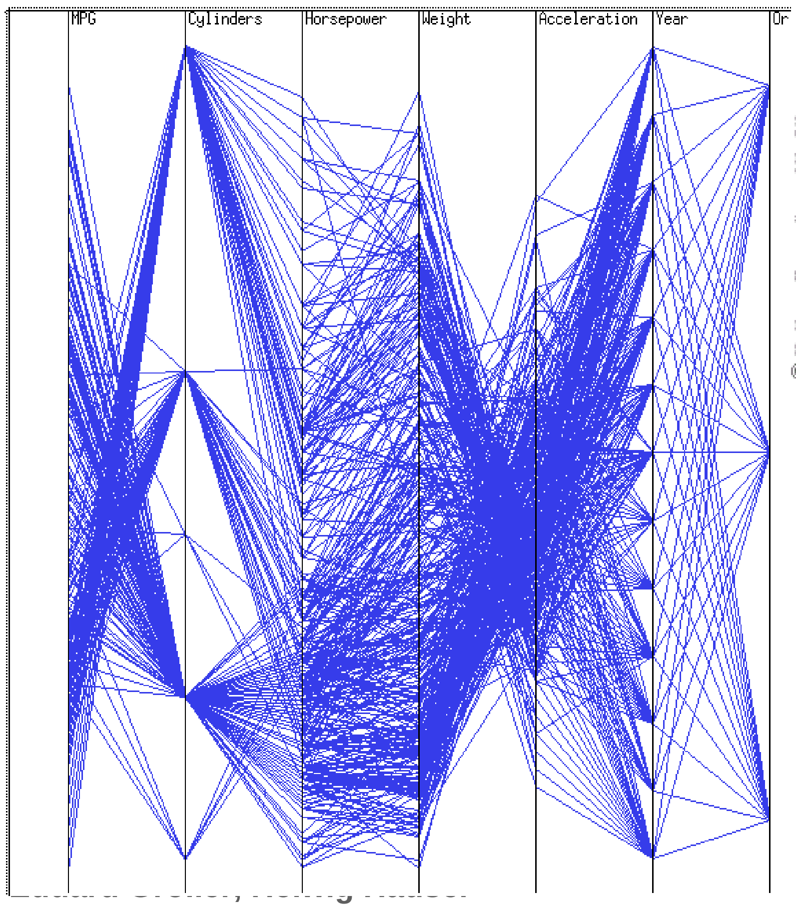
data	description	visualization example
$R^3 \rightarrow R^1$	3D-densities	iso-surfaces in 3D, volume rendering

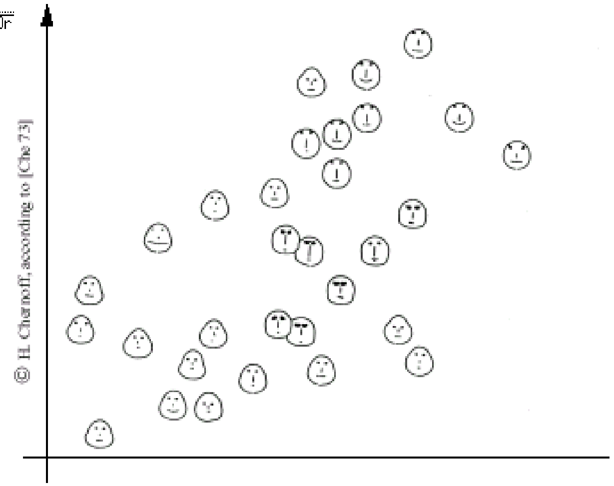


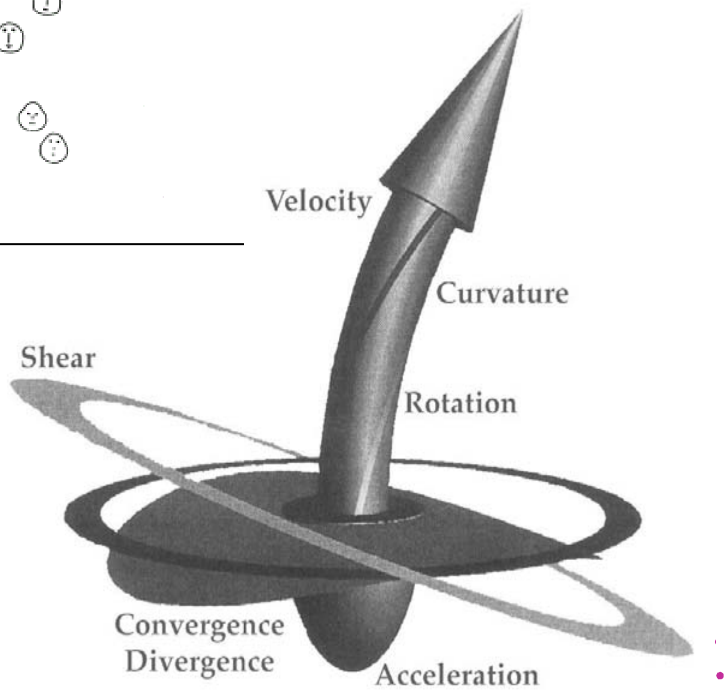


Visualization Examples

data	description	visualization example
$(N^1 \rightarrow)R^n$	set of tuples	parallel coordinates, glyphs, icons, etc.







On Grids

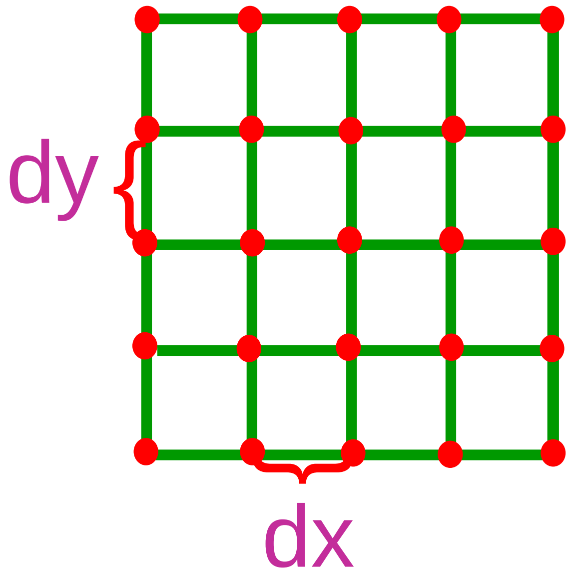
On the organisation of sampled data

Grids – General Information

- Important questions:
  - Which data organisation is optimal?
  - Where do the data come from?
  - Is there a neighborhood relationship?
  - How is the neighborhood info. stored?
  - How is navigation within the data possible?
  - Calculations with the data possible ?
  - Are the data structured?

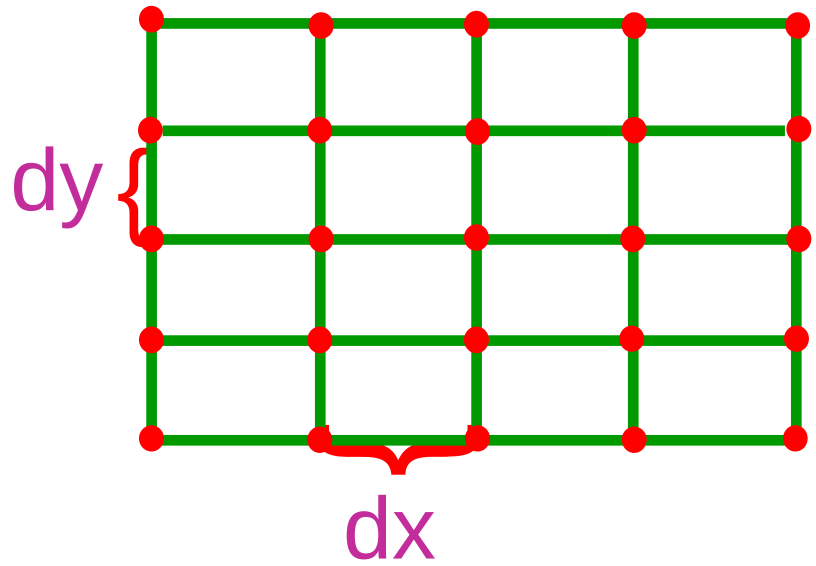
Cartesian Grid

- Characteristics:
  - Orthogonal, equidistant grid
  - Uniform distances (in all dims., dx=dy)
  - Implicit neighborhood-relationship (cf. array of arrays)



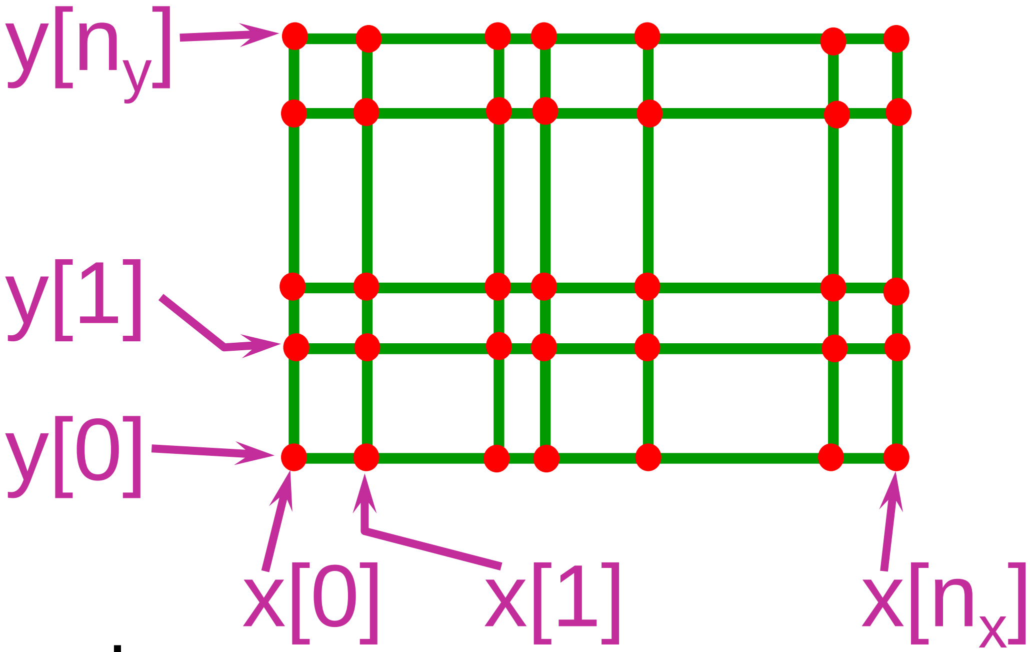
Regular Grid

- Characteristics:
  - Orthogonal, equidistant grid
  - Sample-distances not equal (dx≠dy)
  - Implicit neighborhood-relationship



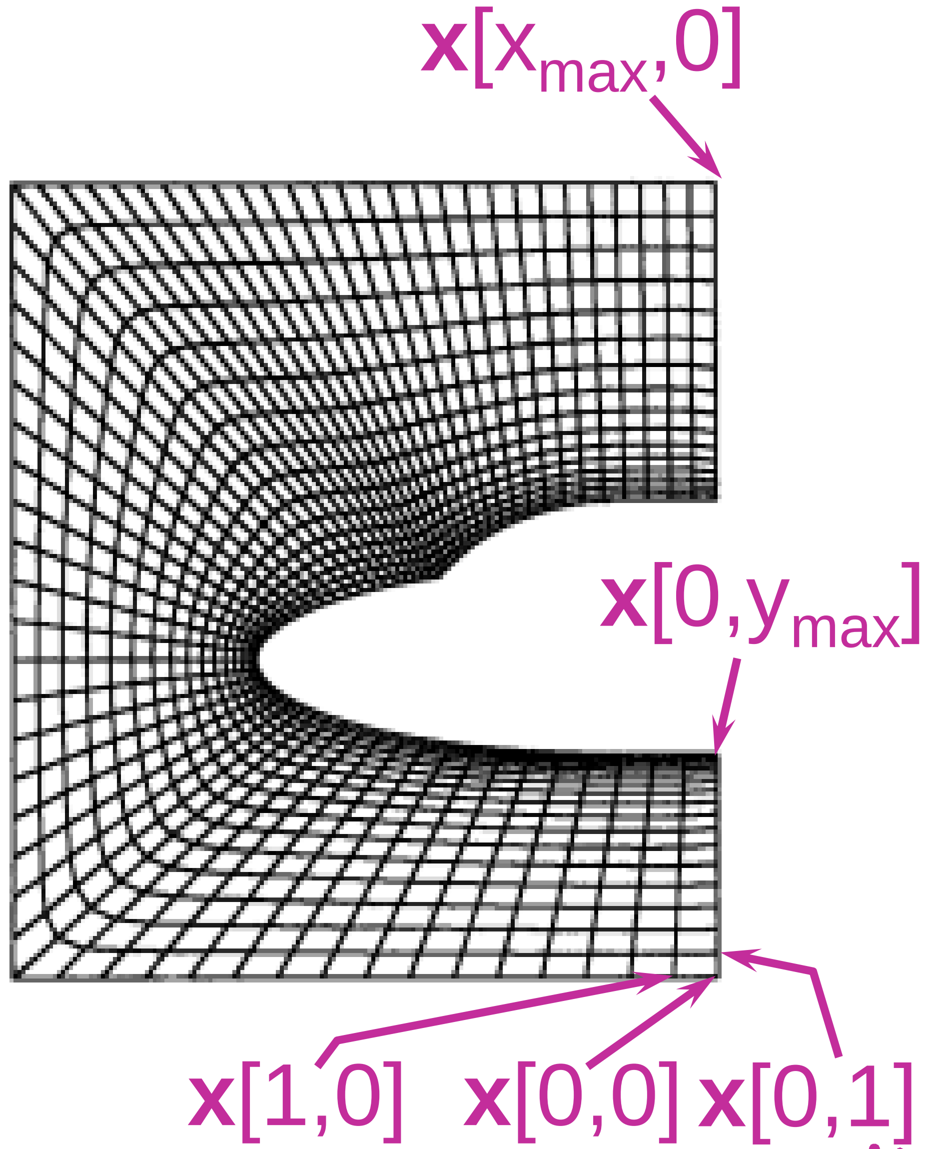
Rectilinear Grid

- Characteristics:
  - Orthogonal grid
  - varying sample-distances (x[i], y[j] given)
  - Implicit neighborhood-relationship



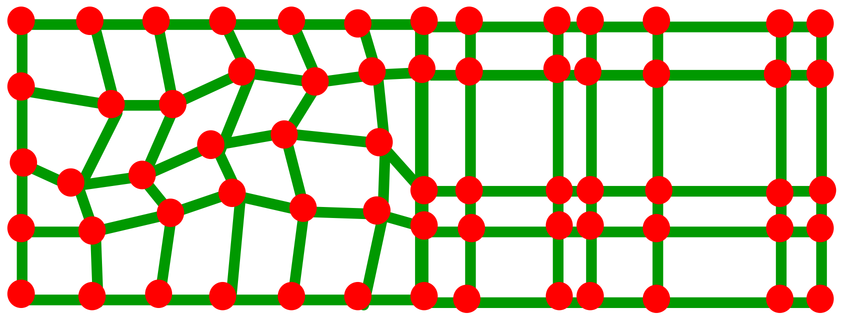
Curvilinear Grid

- Characteristics:
  - non-orthogonal grid
  - grid-points explicitely given (**x**[i,j])
  - Implicit neighborhood-relationship



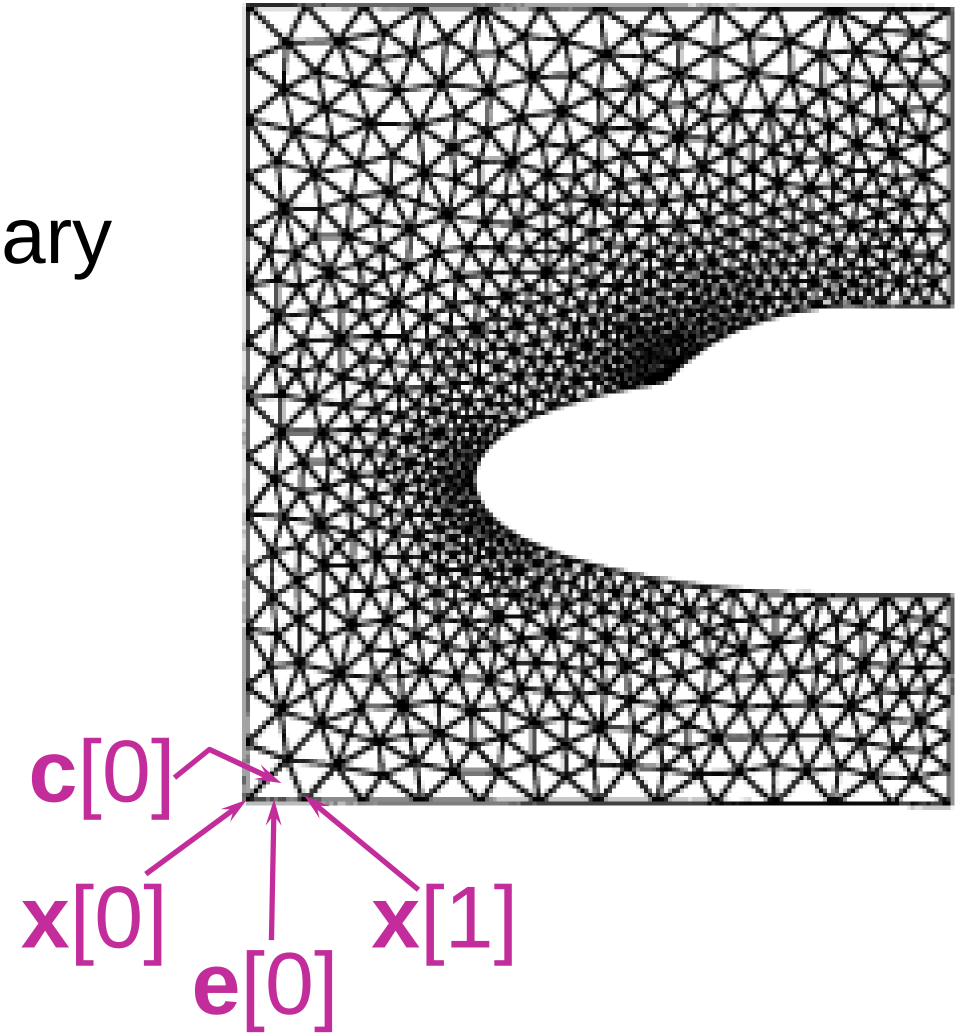
Block-Structured Grid

- Characteristics:
  - Combination of structured grids
  - Each block specified separately
  - Implicit neighborhood-relationship
  - Interface between blocks has to be considered



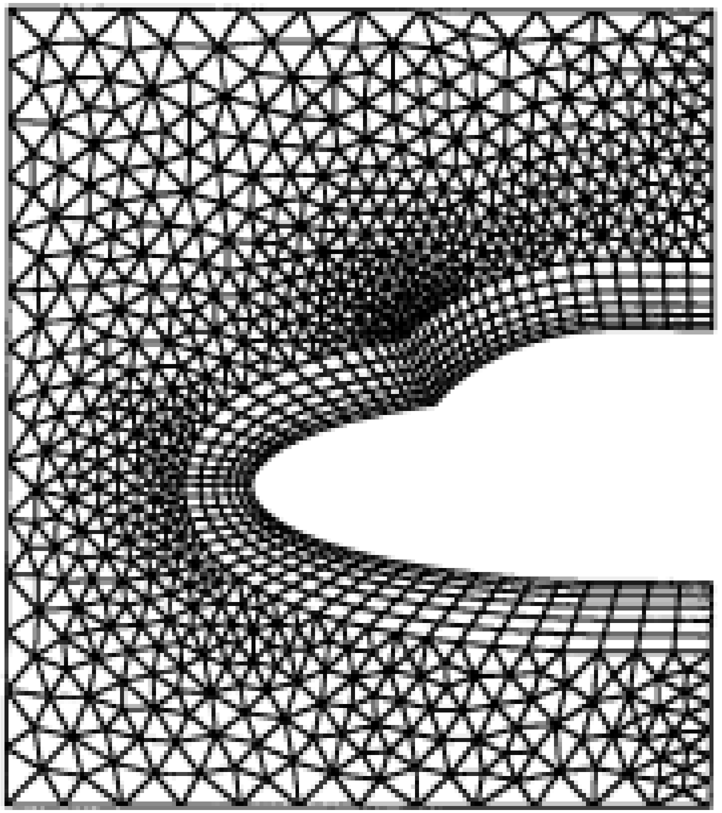
Unstructured Grid

- Characteristics:
  - Grid-points and connections arbitrary
  - Grid-points and neighborhood explicitly given
  - Cells: tetrahedra, hexahedra



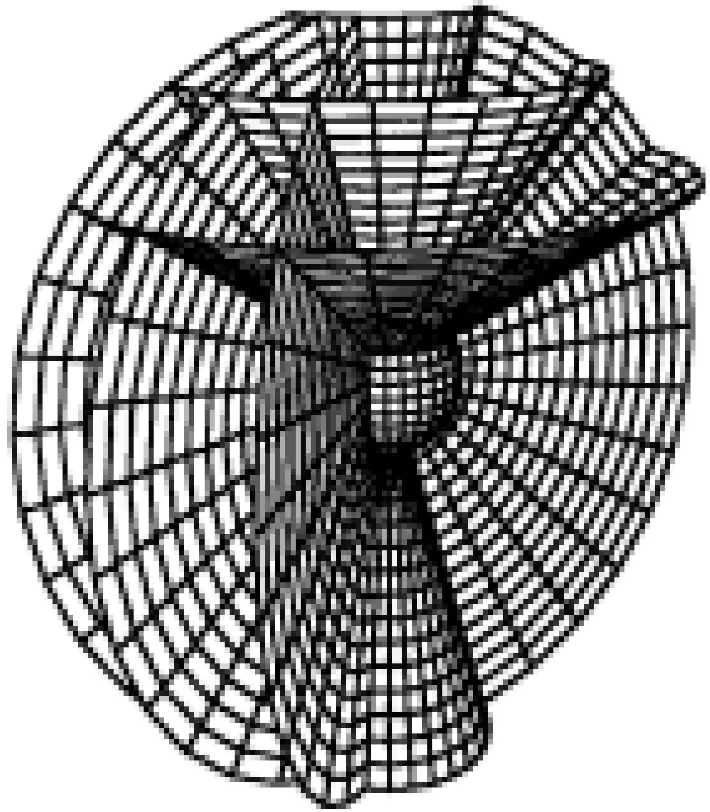
Hybrid Grid

- Characteristics:
  - Combination of structured and unstructured grids
  - Sub-grids specified separately
  - Interface between sub-grids has to be considered

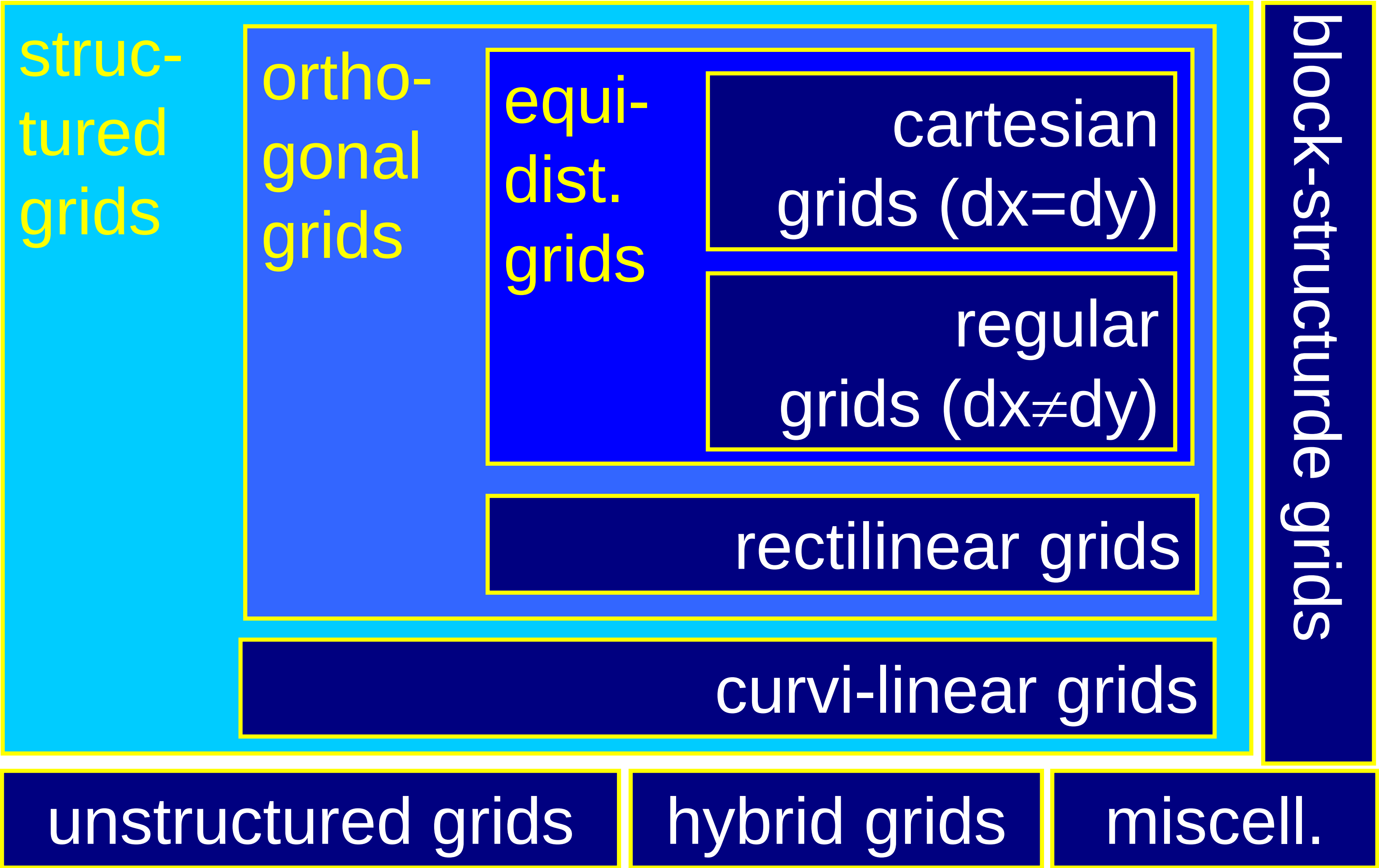


Grids – Miscellaneous

- Characteristics:
  - Non-cartesian coordinates
  - Hierarchical grids
  - Time-varying grids
  - maybe implicit, but alternative neighborhood-relationship

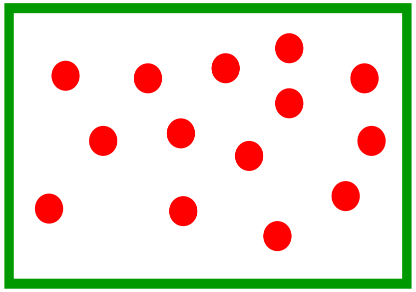


Grids - Survey



Scattered Data

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

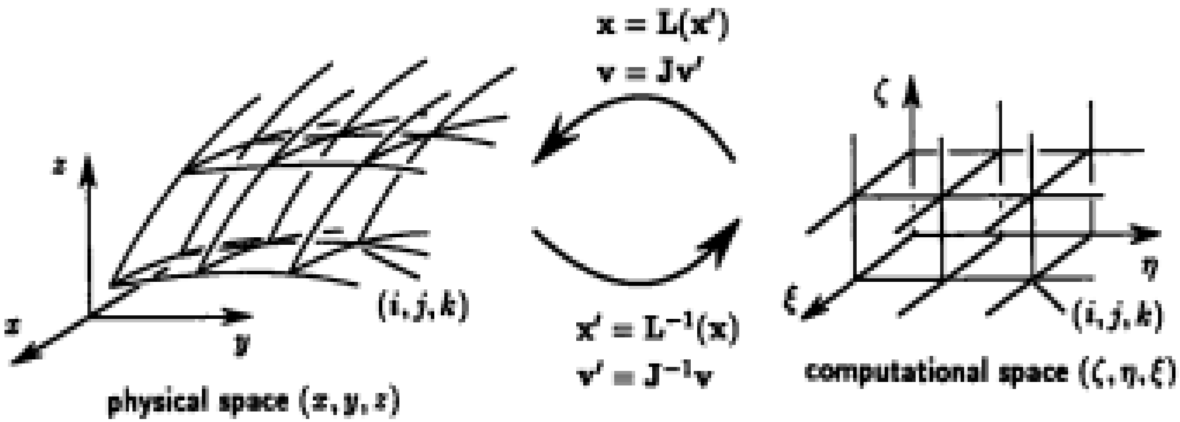


Grid Transformations

- Conversion between grids:
  - physical domain (simulation)
  - computational domain (visualization mapping)
  - image domain (rendering)
  - etc.
- Questions:
  - Accuracy of re-sampling!
  - Design of algorithms

Conversion of Values / Vectors

- Conversion L:
  - $(x,y)=L(i,j)$
  - $(i,j)=L^{-1}(x,y)$



- Jacobi-matrix J
  - Matrix of partial derivatives
  - $J=\nabla L=(dL/di,dL/dj)$
- Conversion of vectors with $J=\nabla L$
  - $v_{ph}(x,y)=J|_{(i,j)}\cdot v_c(i,j)$
  - $v_c(i,j)=J^{-1}|_{(x,y)}\cdot v_{ph}(x,y)$

Visualization and Color

Guidelines for the Usage of Color in Visualization

Usage of Color

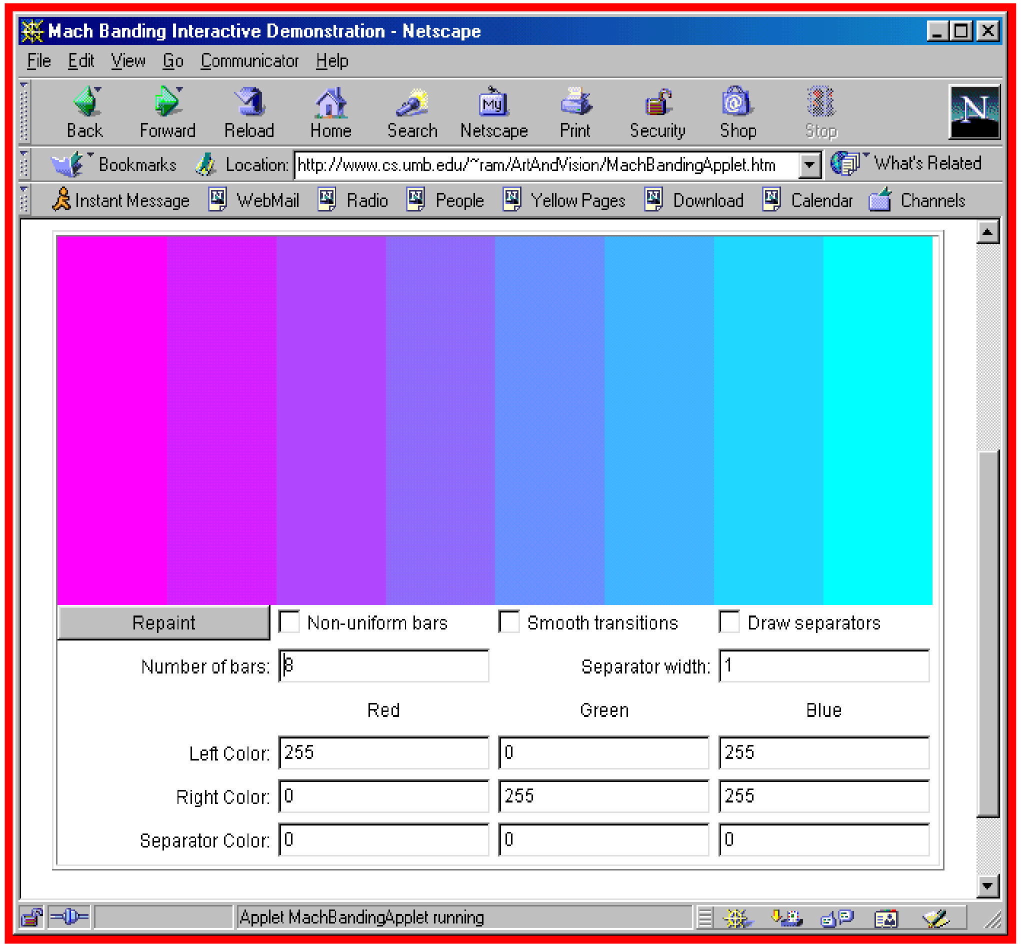
- Some facts:
  - Color can emphasize information
  - Number of colors only 7±2
  - Appr. 50–300 shades distinguishable (different for different colors)
  - Rainbow color scale ≠ linear!
  - Color perception strongly depends on context
  - Color blind users are handicapped
  - Observe color associations

Color Associations

	sensation	taste	temp.	weight
blue	bright: soft dark: hard	neutral	cool, cold	bright: light, dark: heavy
red	rough	spicy, crispy	warm, hot	(as blue)
green	-	bitter	cool	(as blue)
yellow	soft	sweet	warm, hot	light
pink	very soft	sweetish	skin- temp.	light

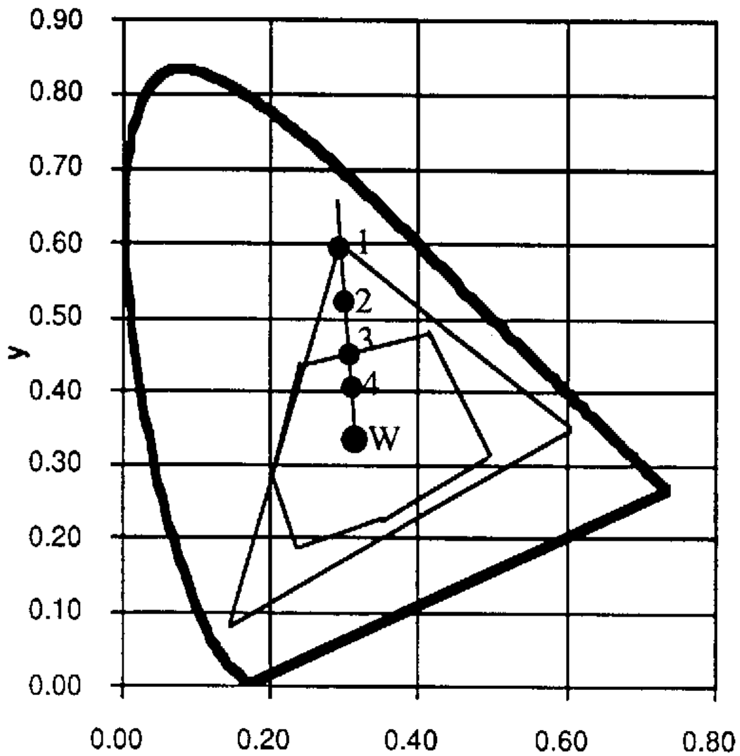
Mach-Banding

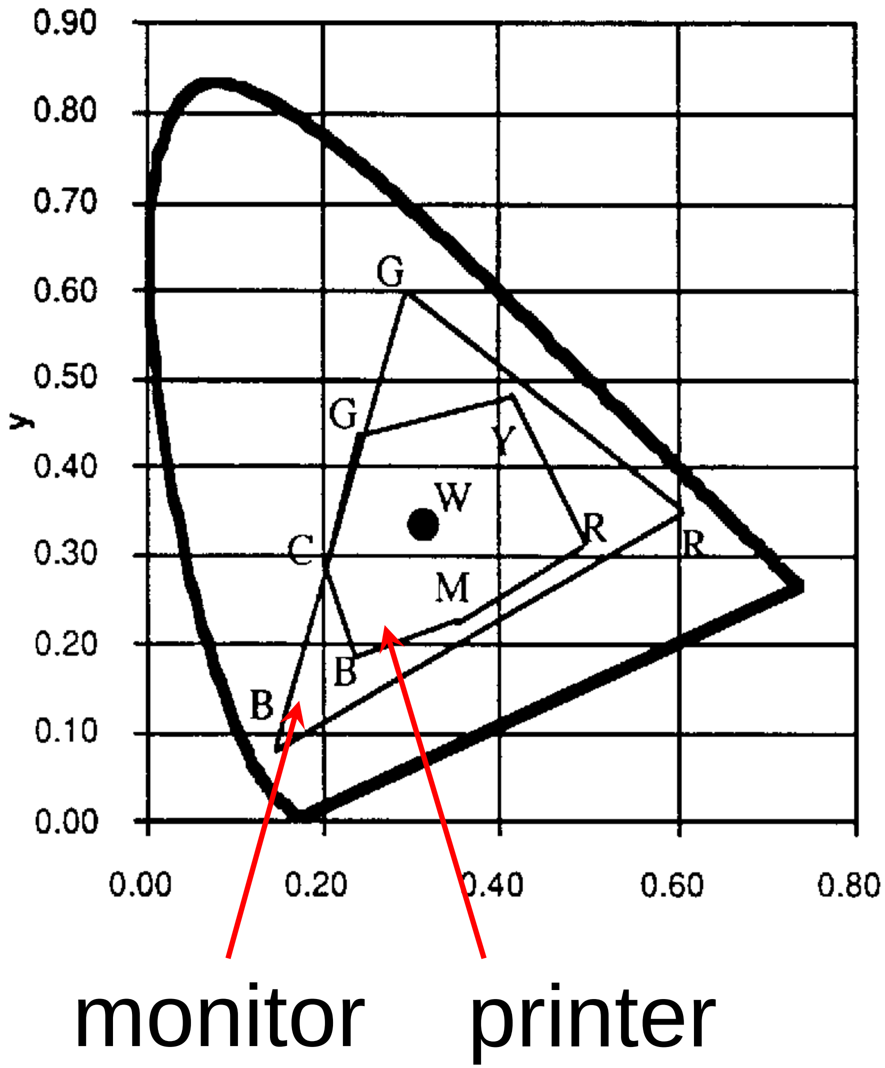
- Eye emphasizes edges
- Discretization errors stand out
- Attention when using colors, intensities



Color Gamuts

- Devices different
  - Color spaces not congruent
  - Color correction





Guidelines for Usage of Color

- Desaturated lines as border of colored areas
- No saturated blue for details, animations
- do not mix saturated blue and red
  (why? therefore)
- Avoid high color frequencies
- Colors to compare should be close
- Observe context, associations!
- Well suited: color for qualitative visualization
- Use redundancy (shape, style, etc.)

Acknowledgement

- Thanks for material for this lecture unit:
  - Inge Tastl
  - etc.