Spatial Layout

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CS 558: Visualization
Winter 2005

Lecture adapted from Hanrahan 2004

Topics

Cartographic projections and distortions
Viewing projections
Displaying data in graphs
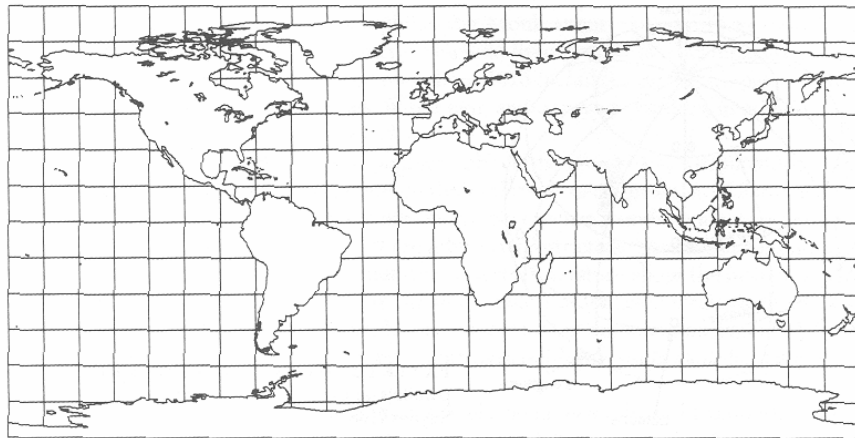**Fitting data and depicting residuals**
Displaying multidimensional data
Graphical calculations
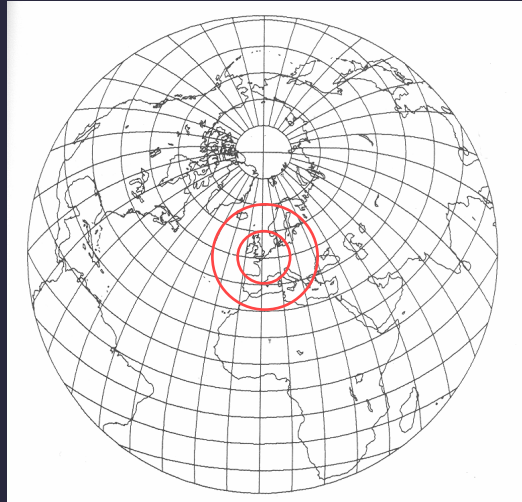**Reorderable spaces**

Cartographic Projections

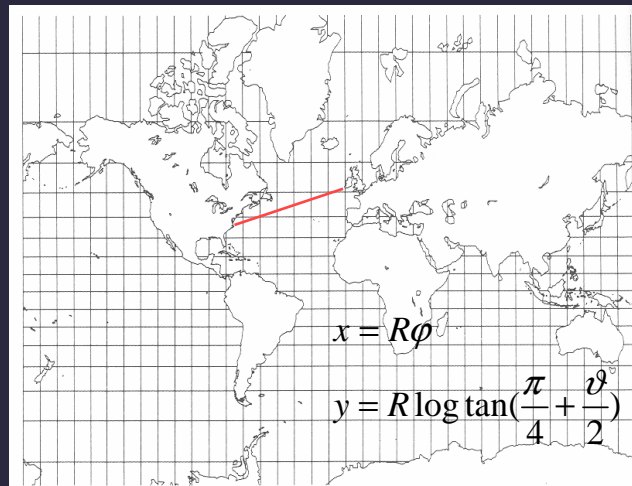# Latitude-longitude projection

[Figure 1.3, *Flattening the Earth*, Snyder]

Azimuthal equidistance
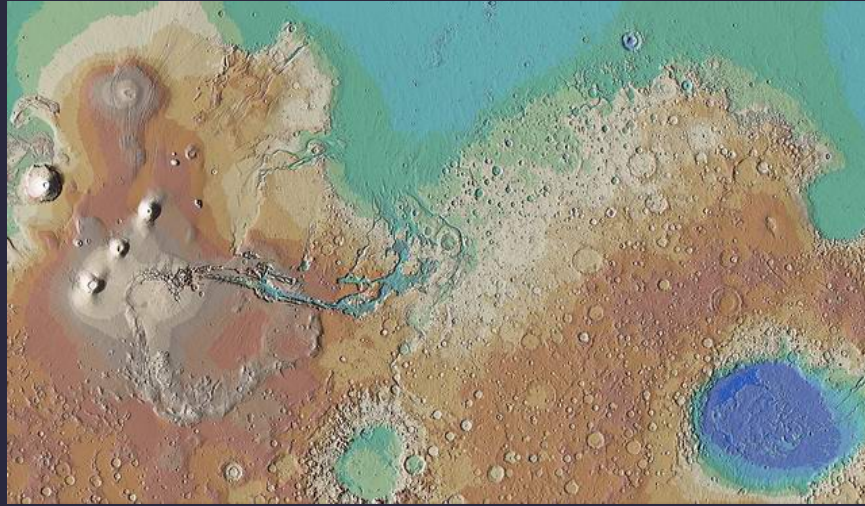

[Figure 3.4, *Flattening the Earth*, Snyder]

Mercator projection (equiangular)

$$x = R\varphi$$

$$y = R\log\tan(\frac{\pi}{4} + \frac{\vartheta}{2})$$

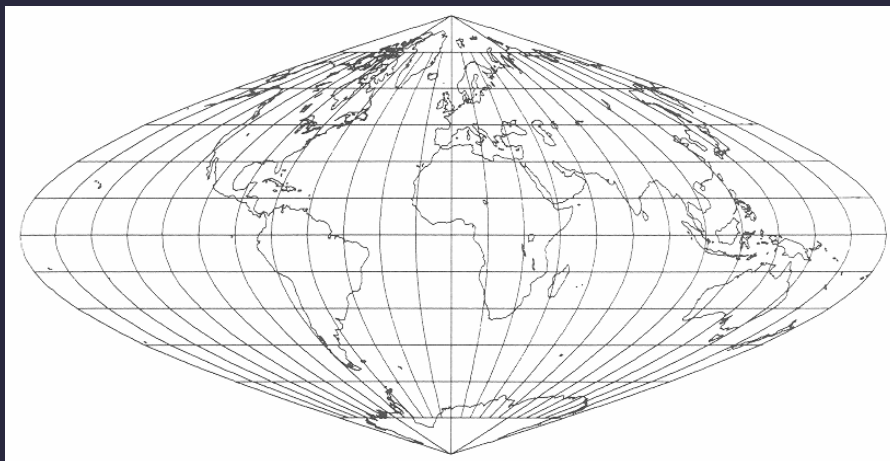[Figure 1.35, *Flattening the Earth*, Snyder]
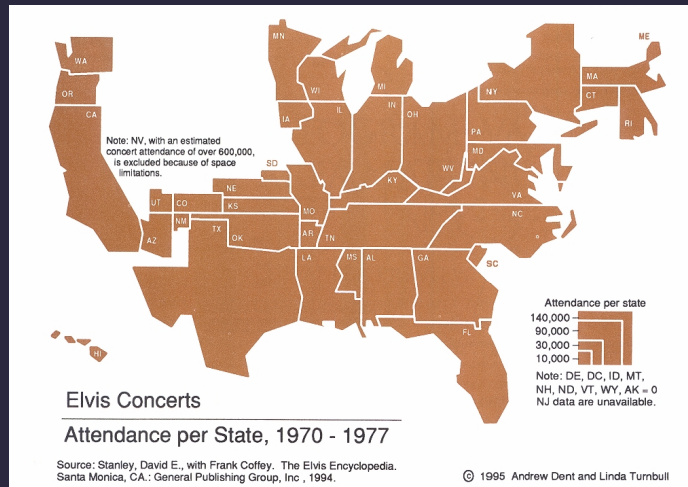
Mercator projection

Circular craters map to circles

USGS Map of Mars

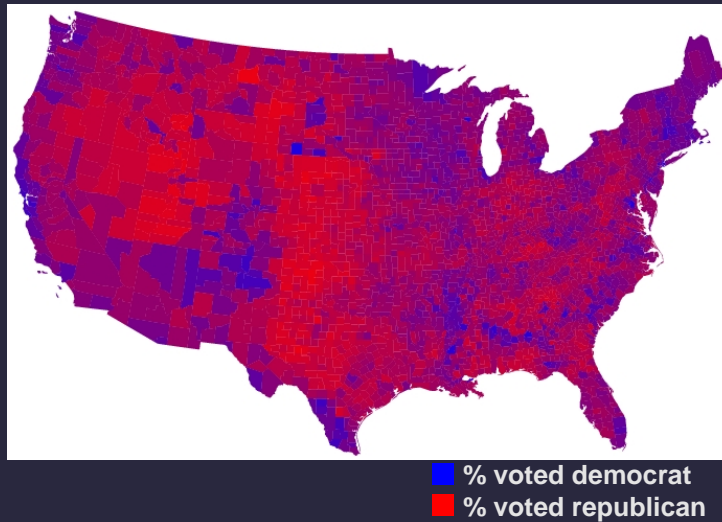# Sinusoidal equiareal projection

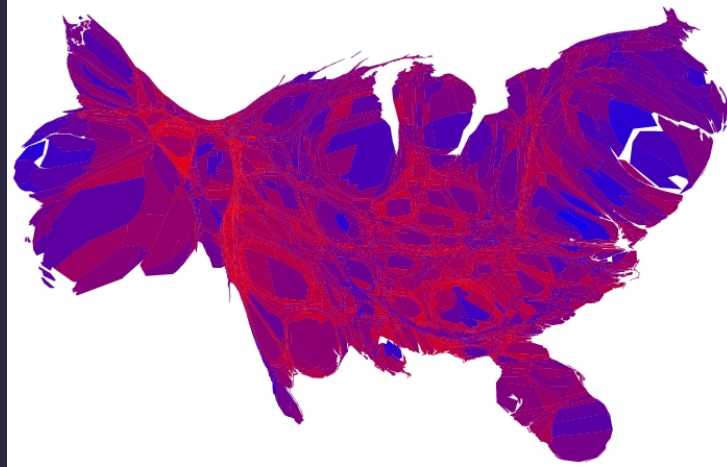[Figure 1.39a, *Flattening the Earth*, Snyder]

Cartograms: Distort areas

Elvis Concerts
Attendance per State, 1970 - 1977

Source: Stanley, David E., with Frank Coffey. The Elvis Encyclopedia.
Santa Monica, CA.: General Publishing Group, Inc , 1994.

Note: NV, with an estimated concert attendance of over 600,000, is excluded because of space limitations.

Attendance per state
140,000
90,000
30,000
10,000

Note: DE, DC, ID, MT, NH, ND, VT, WY, AK = 0
NJ data are unavailable.

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Scale area by data

[From *Cartography*, Dent]

Election 2004 map

■ % voted democrat
■ % voted republican

http://www-personal.umich.edu/~mejn/election/

Election 2004 cartogram

■ % voted democrat
■ % voted republican

http://www-personal.umich.edu/~mejn/election/

Statistical map with shading

MURDER RATES, 1978

⬚ 1.2
⬚ 4.9
⬚ 8.5   FIVE REPRESENTATIVE
          SHADINGS
⬚ 12.1
■ 15.8
RATES PER 100,000 POPULATION

Figure 5. Statistical map with shading.
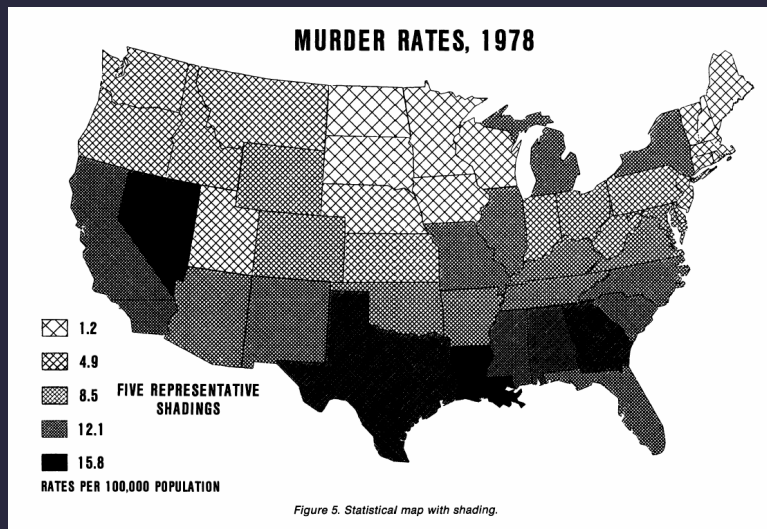
[Cleveland and McGill 84]

Framed rectangle chart

[] = 0   [] = 4   [] = 8   [] = 12   [] = 16

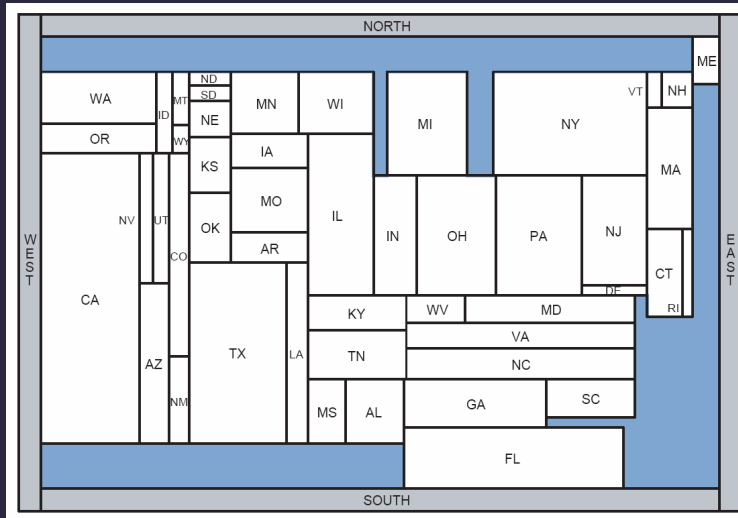MURDER RATES PER 100,000 POPULATION, 1978
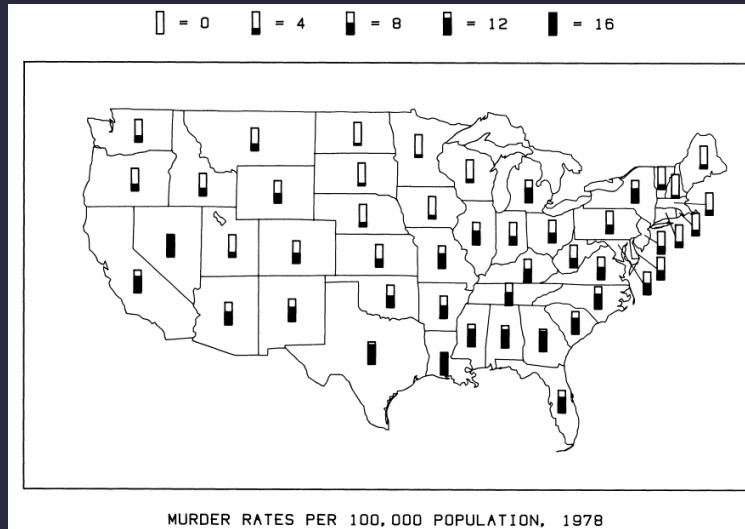
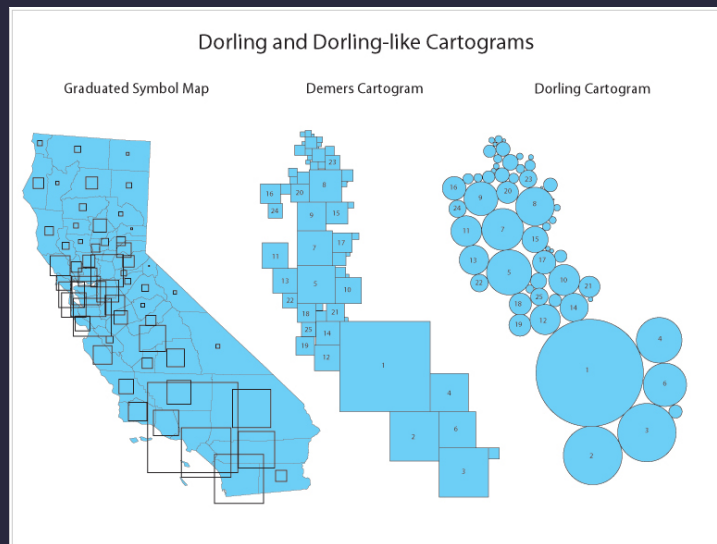[Cleveland and McGill 84]

Rectangular cartogram
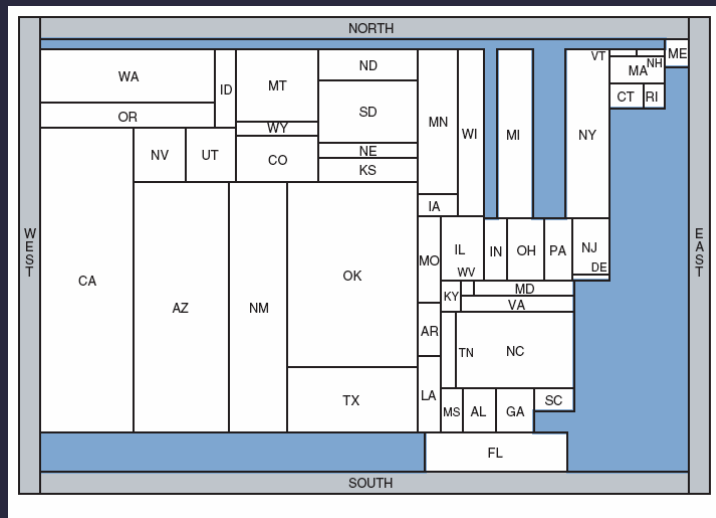
Native American population [van Kreveld and Speckmann 04]
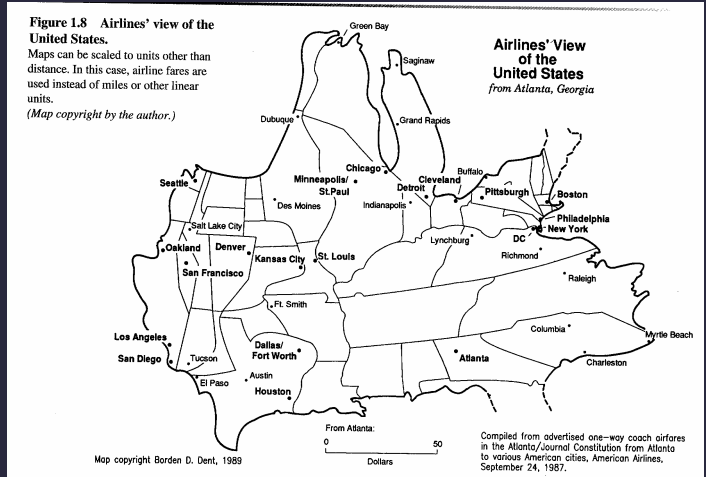
Rectangular cartogram

American population [van Kreveld and Speckmann 04]

Dorling cartogram

http://www.ncgia.ucsb.edu/projects/Cartogram_Central/types.html

Distorting distances

Scale distance by data

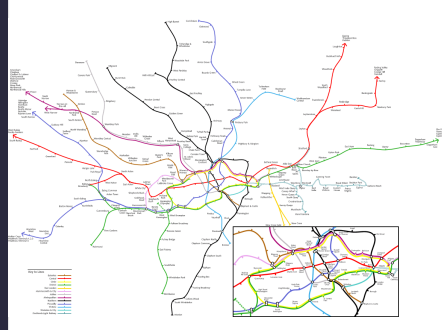[From *Cartography*, Dent]

London underground

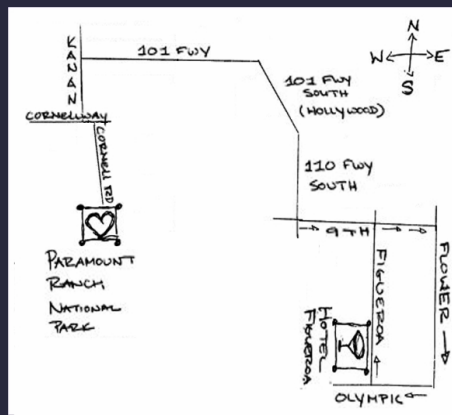http://www.thetube.com/content/history/map.asp

9

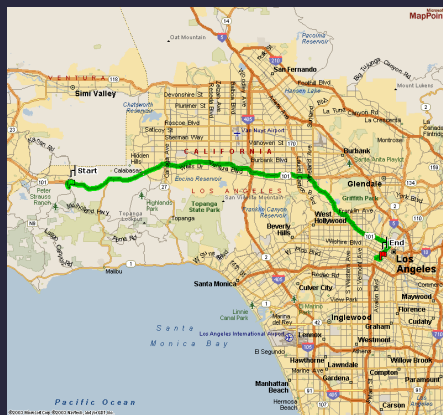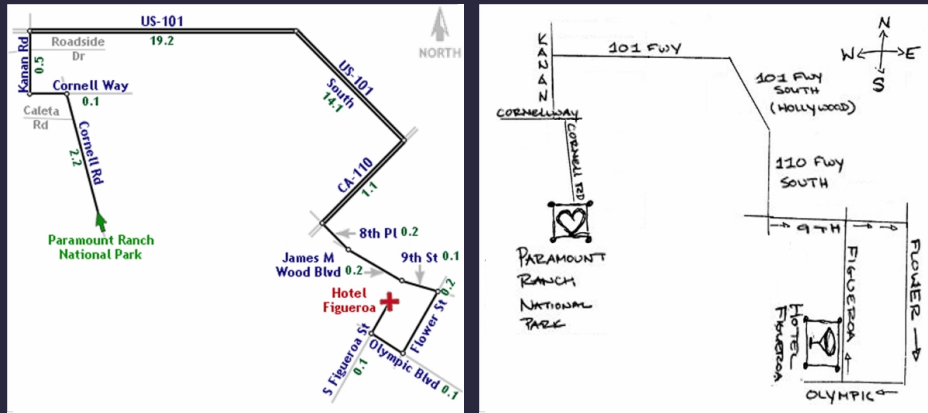# Comparison to geographic map

Distorted

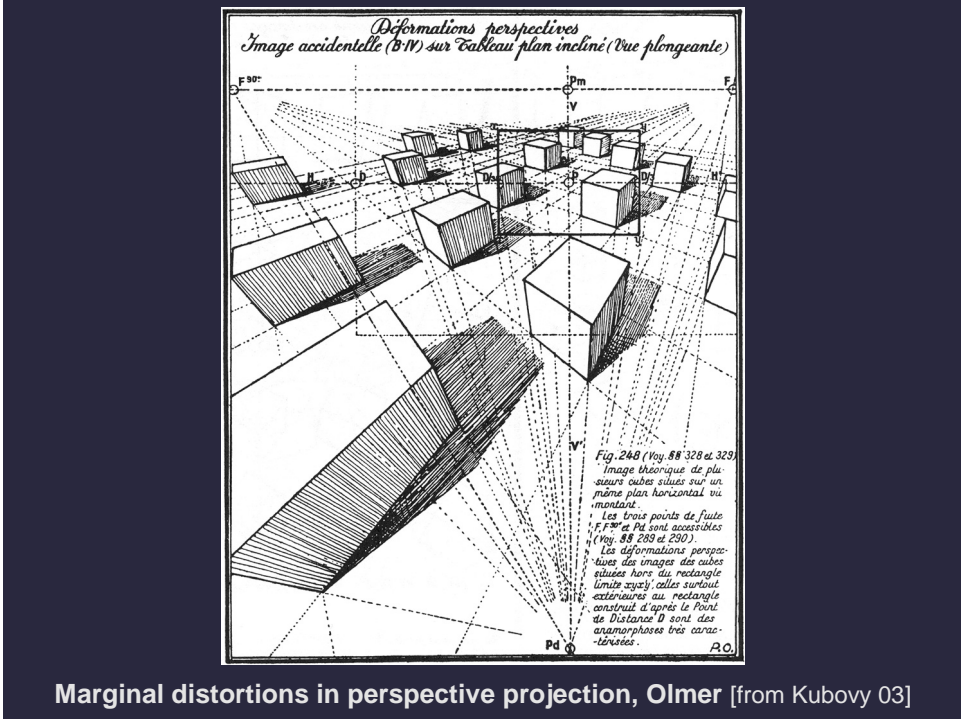**Undistorted**

Route maps

1. **Expand short roads**
2. **Contract long roads**
3. **Straighten wiggly lines**
4. **Snap turn directions to right angles**
5. **Label carefully to avoid clutter**
6. **Maintain overall orientation**

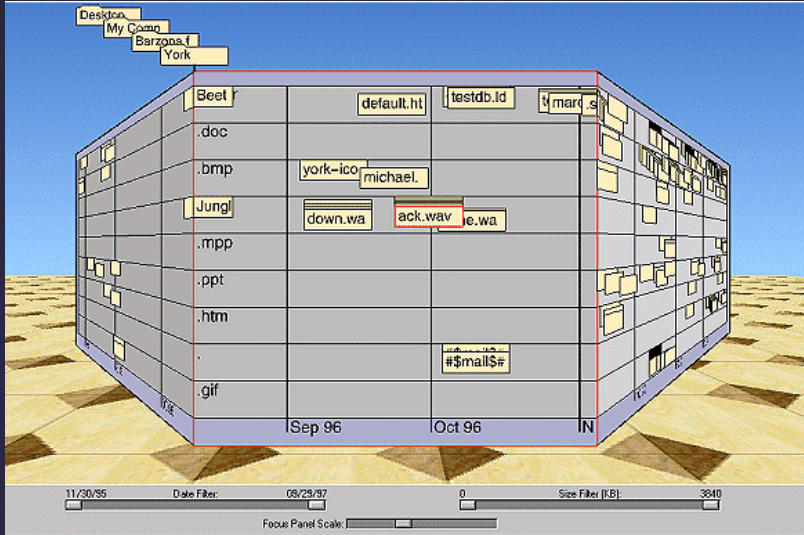# Route maps: LineDrive [Agrawala & Stolte 01]

Distortions improve effectiveness
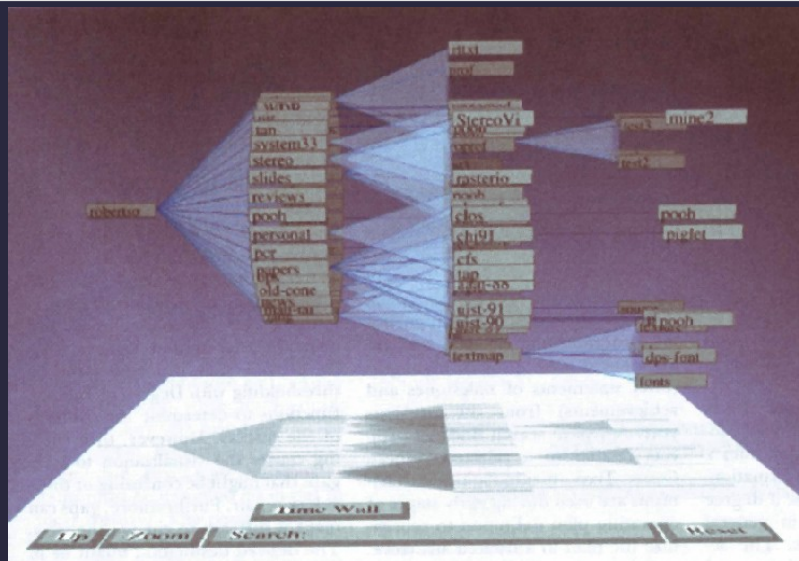
Perspective

Marginal distortions in perspective projection, Olmer [from Kubovy 03]
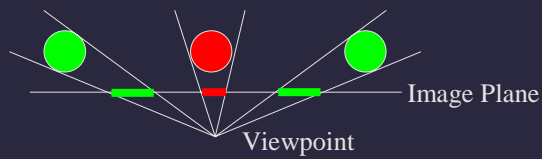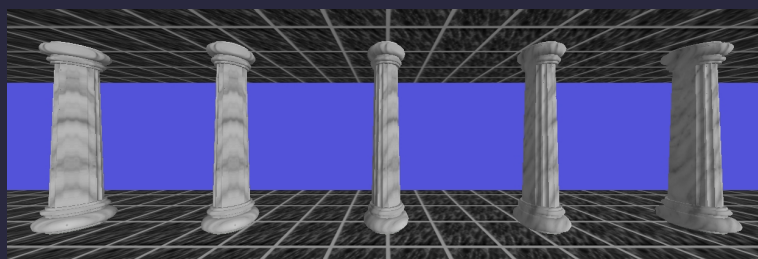
Perspective allows more context

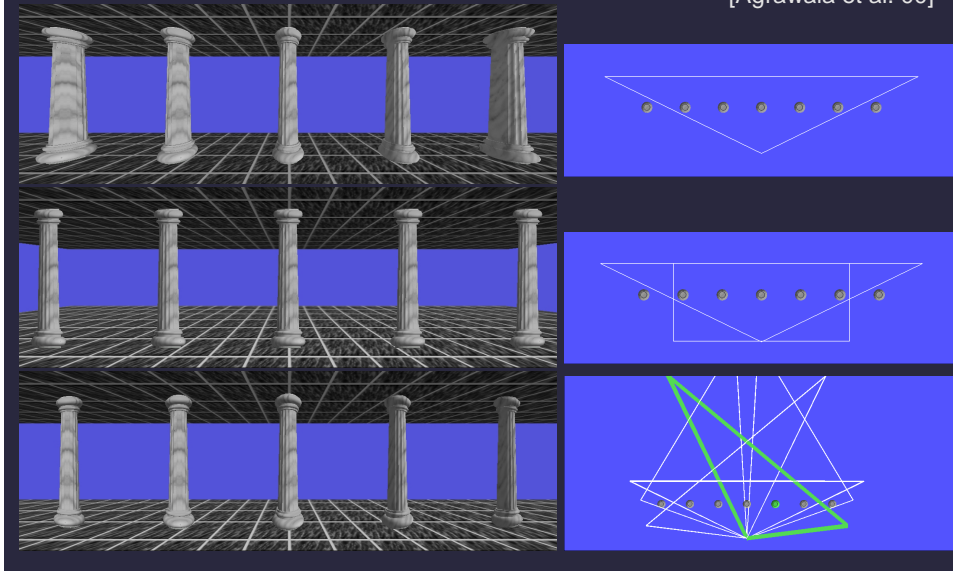**Perspective Wall** [Mackinlay et al. 91]

Perspective allows more context

Cone Trees [Robertson et al. 91]

Wide-angle distortion

Image Plane

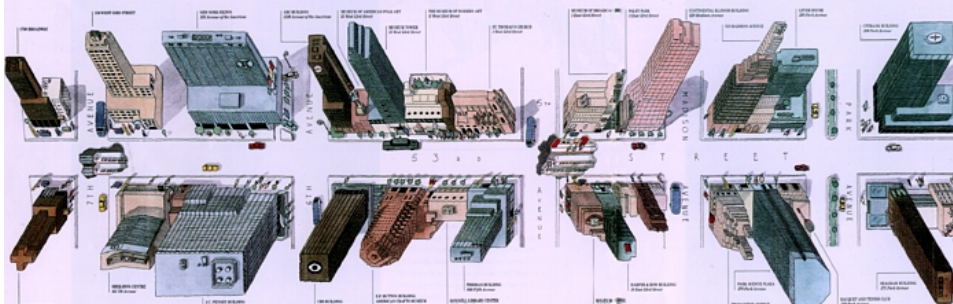Viewpoint

Correction via multiple projections
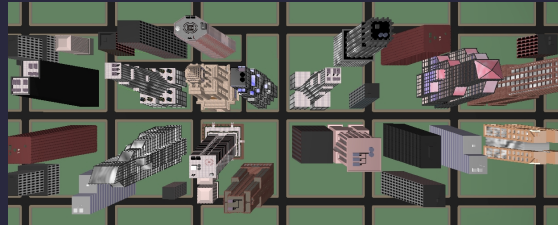
[Agrawala et al. 00]

Artificial perspective

Multiple parallel (oblique) projections
- Orient receding parallel towards vanishing point
- Some area comparisons possible

53rd Street Map [Guarnaccia 93]
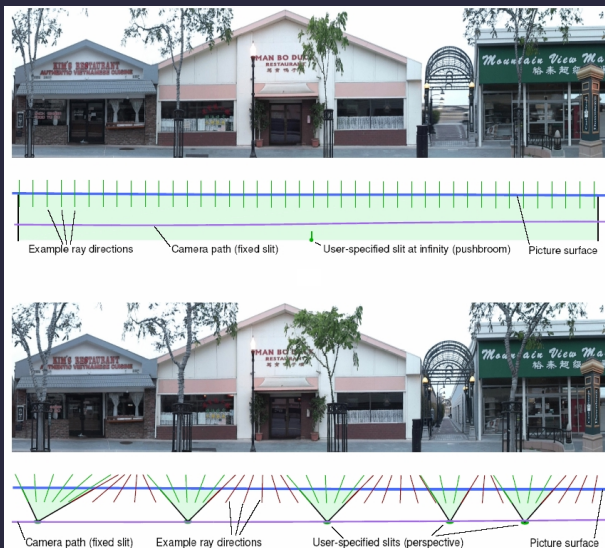
CG example of artificial perspective

Multiple oblique projections

Standard perspective projection

[Agrawala et al. 00]

Multiperspective panoramas

Example ray directions Camera path (fixed slit) User-specified slit at infinity (pushbroom) Picture surface

Camera path (fixed slit) Example ray directions User-specified slits (perspective) Picture surface
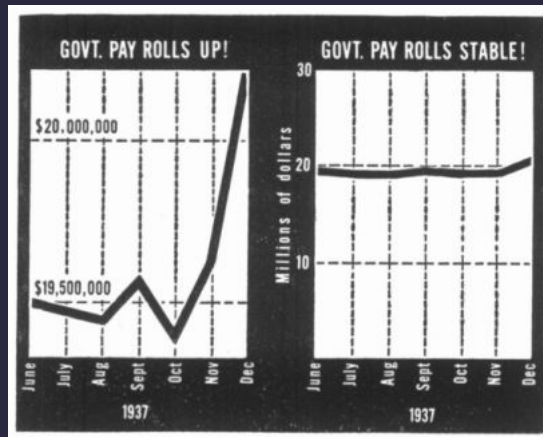
[Román et al. 04]

Issues

- **Choose coordinate systems that support geometric reasoning**

- **Tension between geometric properties**
  - Equiarea implies not equiangular
  - Modern projections seek compromise

- **People tolerate distortion -- to an extent**
  - Maintain important information
  - Avoid extremes

Graphs and Lines

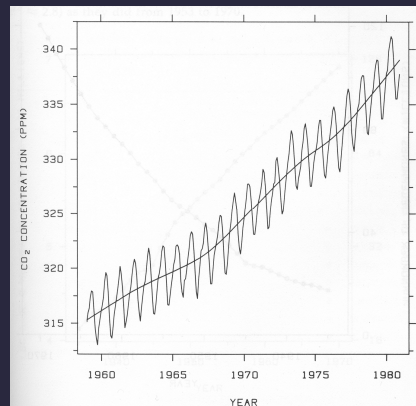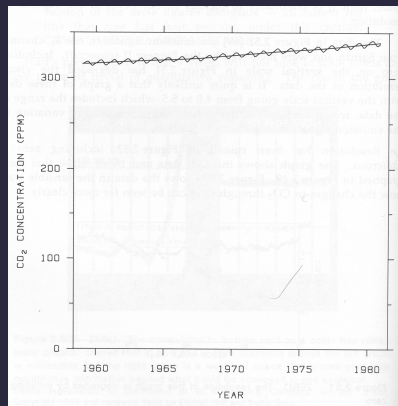# Effective use of space

Which graph is better?

Government payrolls in 1937 [How To Lie With Statistics. Huff 93]

Aspect ratio

Fill space with data
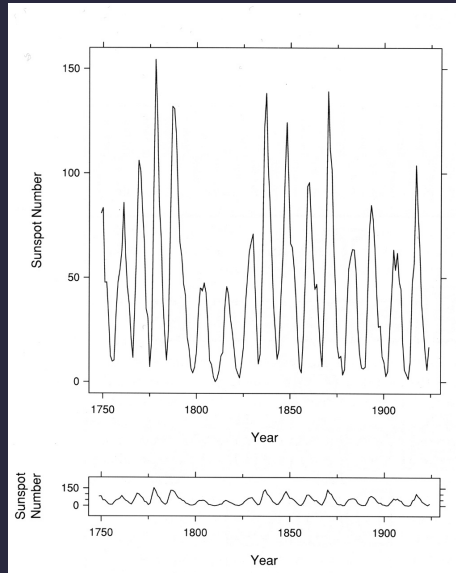**Don't worry about showing zero**

Yearly CO2 concentrations [Cleveland 85]
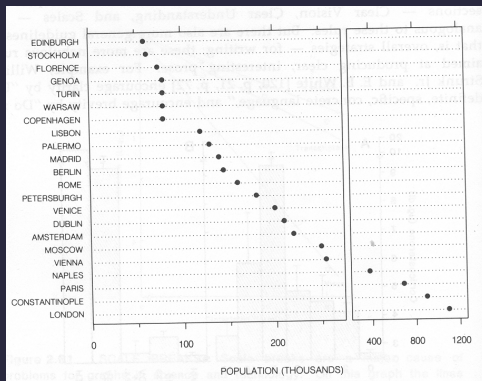
Banking to 45 degrees

Orientation accuracy best at 45 degrees
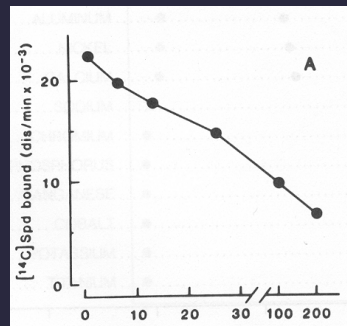
Set aspect ratio accordingly
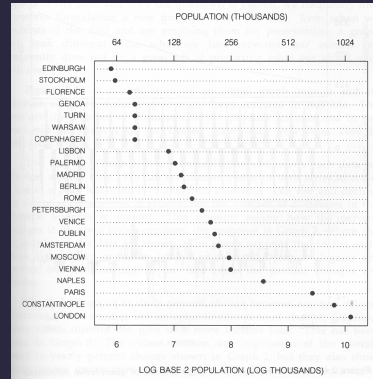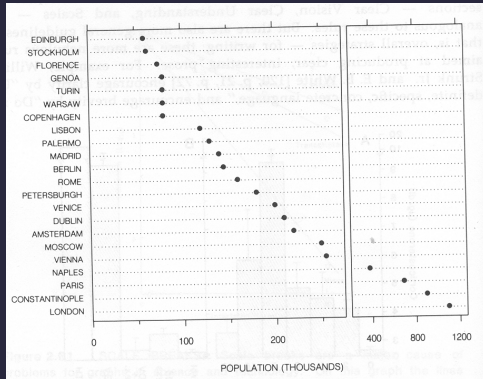
Clearly mark scale breaks

Well marked scale break [Cleveland 85]

Poor scale break [Cleveland 85]
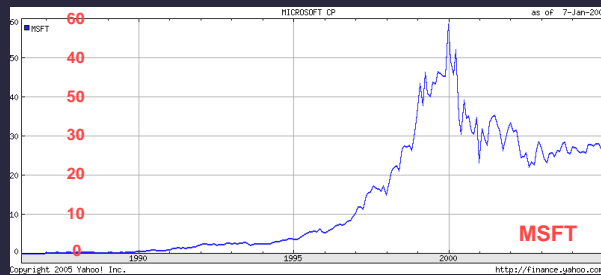
Scale break vs. Log scale

[Cleveland 85]

Both increase visual resolution
- **Log scale - easy comparisons of all data**
- **Scale break – more difficult to compare across break**

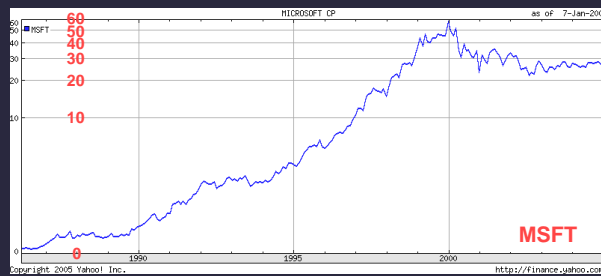---

Linear scale vs. Log scale

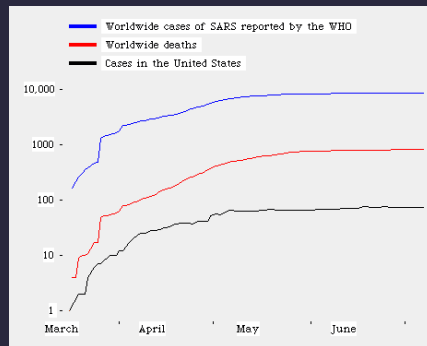**Linear scale**
- **Absolute change**

Log scale
- **Percent change**

$d(10,20) = d(30,60)$

Semilog graph

Exponential functions ($y = ka^{mx}$) transform into lines

$$\log(y) = \log(k) + \log(a)mx$$

SARS cases up March – July 7, 2003
http://www.squeak.org/us/ted/sars-graph.html

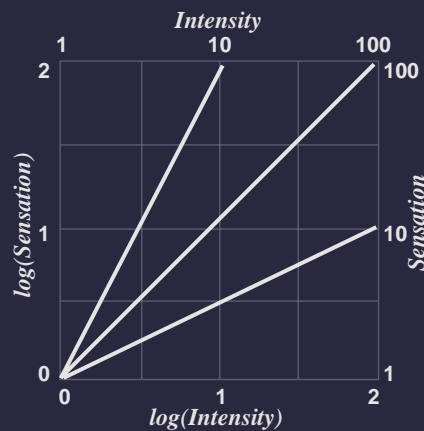**AIDS Cases:** http://www.righto.com/java/statsgraph.html
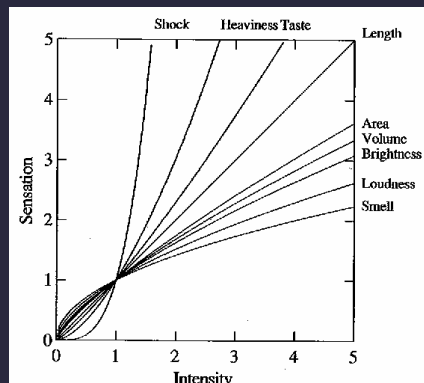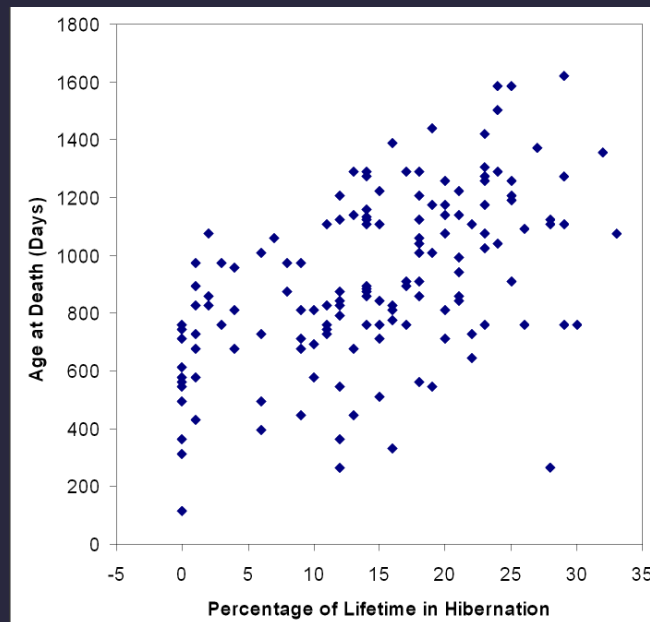
Log-Log graph

Power functions ($y = kx^{a}$) transform into lines

Example - Steven's power laws:

$$S = kI^{p} \rightarrow log\ S = log\ k + p\ log\ I$$

Fitting the Data

[The Elements of Graphing Data. Cleveland 94]
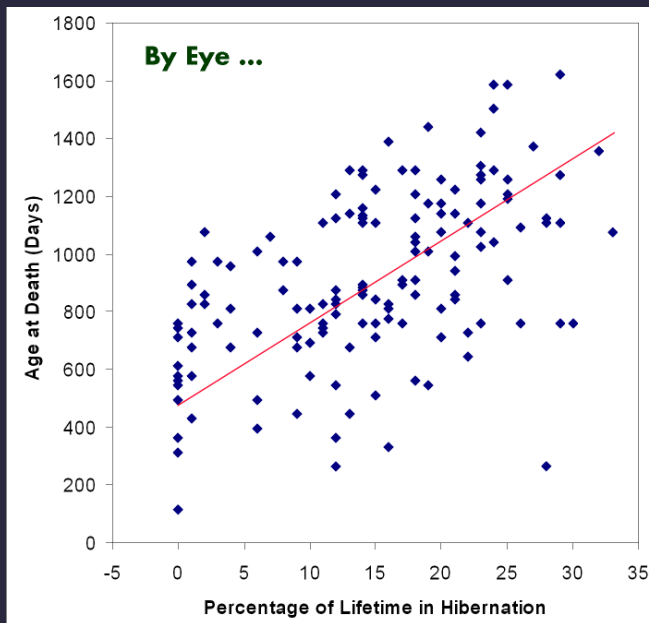
By Eye ...

[The Elements of Graphing Data. Cleveland 94]

Linear regression ...

[The Elements of Graphing Data. Cleveland 94]

22

Linear regression w/out outlier ...
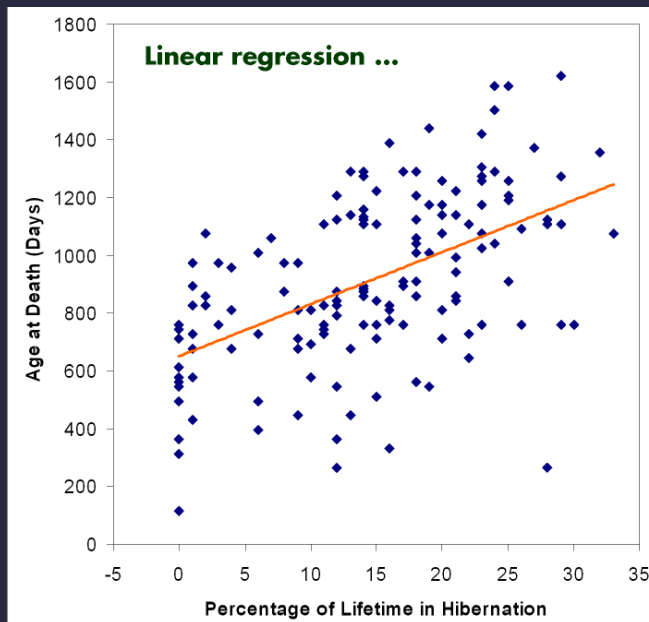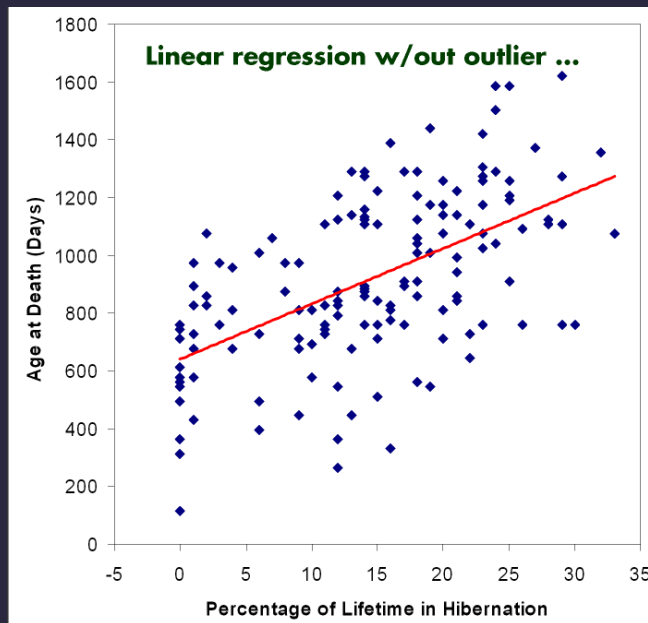
[The Elements of Graphing Data. Cleveland 94]

Transforming the data

Residual graph

- **How well does curve fit data?**
- **Plot vertical distance from best fit curve**
- **Residual graph shows accuracy of fit**

[Cleveland 85]

Tukey sum-difference graph

Plot distance to line $y = x$

- **Rotate top graph by 45 degrees**
- **Scale to increase visual resolution**

[Cleveland 85]

Parallel Coordinates

Parallel coordinates

Visualizing nD in planar image
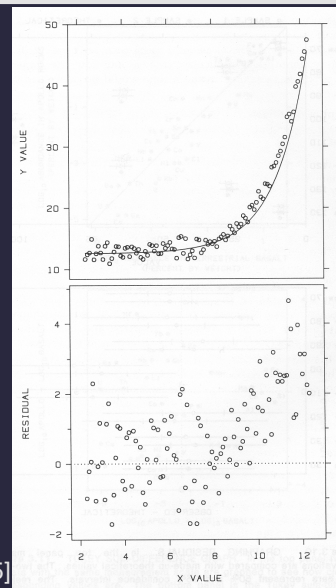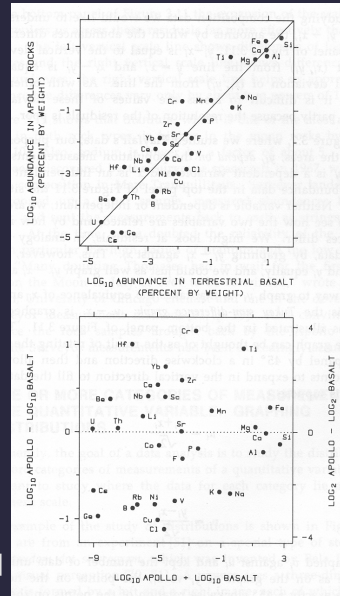- **Only 2 orthogonal axes**
- **Use parallel axes instead**
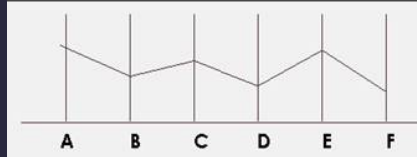
Plot each dimension of point x on separate axis
- $x = (a, b, c, d, …)$
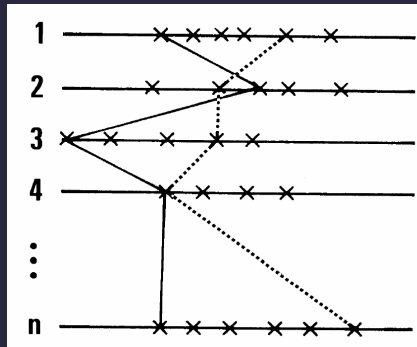
[Wegman 90]

Parallel coordinates: Axis ordering

No intrinsic order
- **True of many nD techniques**
- **Allow interactive axis swap**
  - **Bad: Relies on human examination**
  - **Good: Powerful interaction**
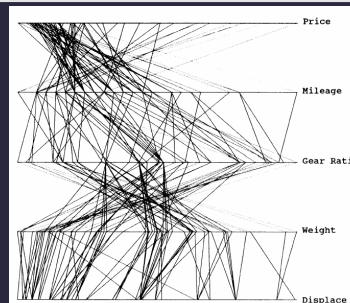
Machine learning
- **Automated multidimensional detective** [Inselberg 99]
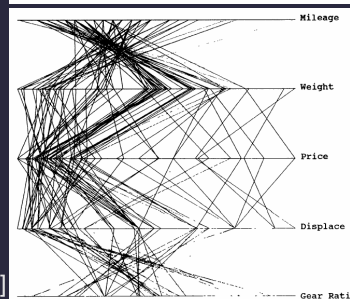
5D Automobile Data [Wegman 90]

Parallel coordinates: Clustering
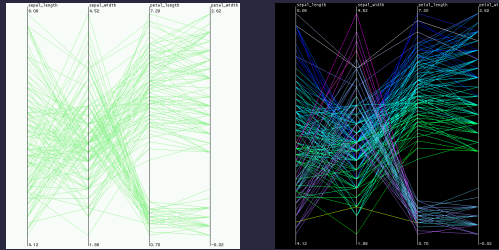
Proximity-based coloring
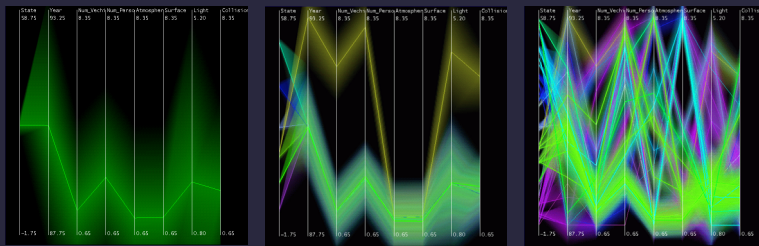
Visualizing hierarchical clusters

[Fua et al. 99]

Graphical Calculations

Nomograms
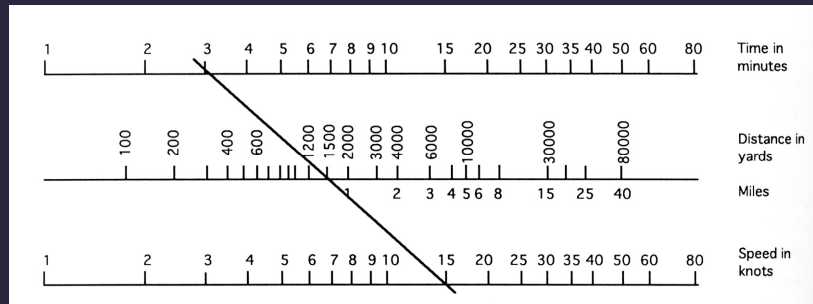
The Rule of Three

Theory

$$\begin{vmatrix} x_1(u) & y_1(u) & w_1(u) \\ x_2(v) & y_2(v) & w_2(v) \\ x_3(s,t) & y_3(s,t) & w_3(s,t) \end{vmatrix} = 0$$

Slide rule
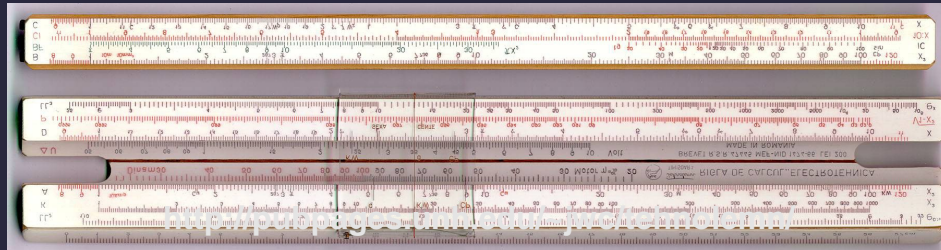
Model 1474-66   Electrotehnica   18 Scales

Tehnolemn Timisoara Slide Rule Archive
http://pubpages.unh.edu/~jwc/tehnolemn/
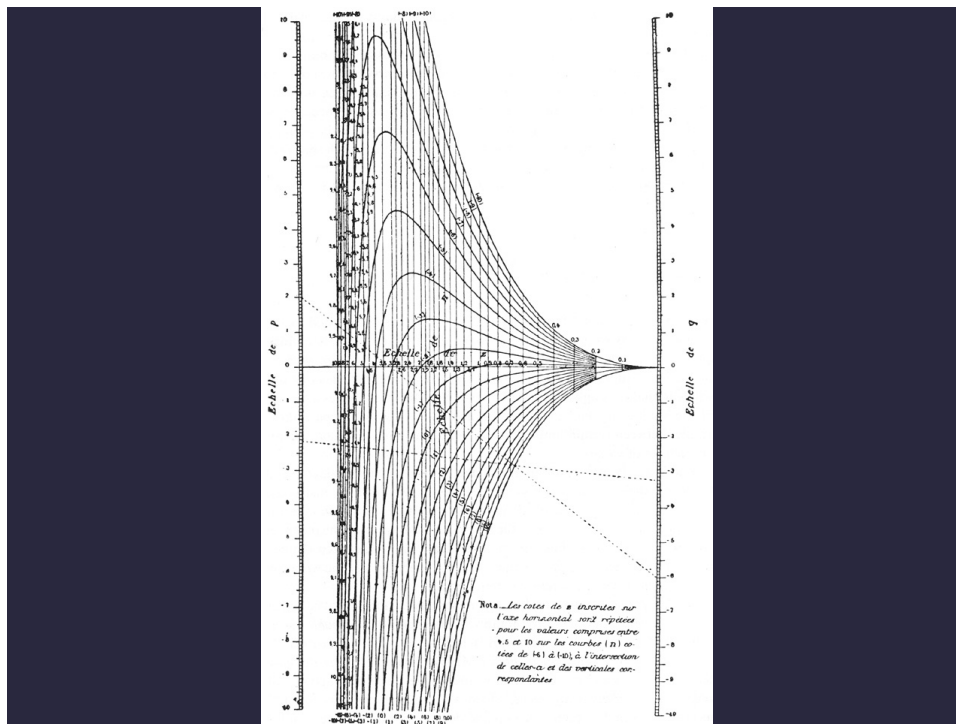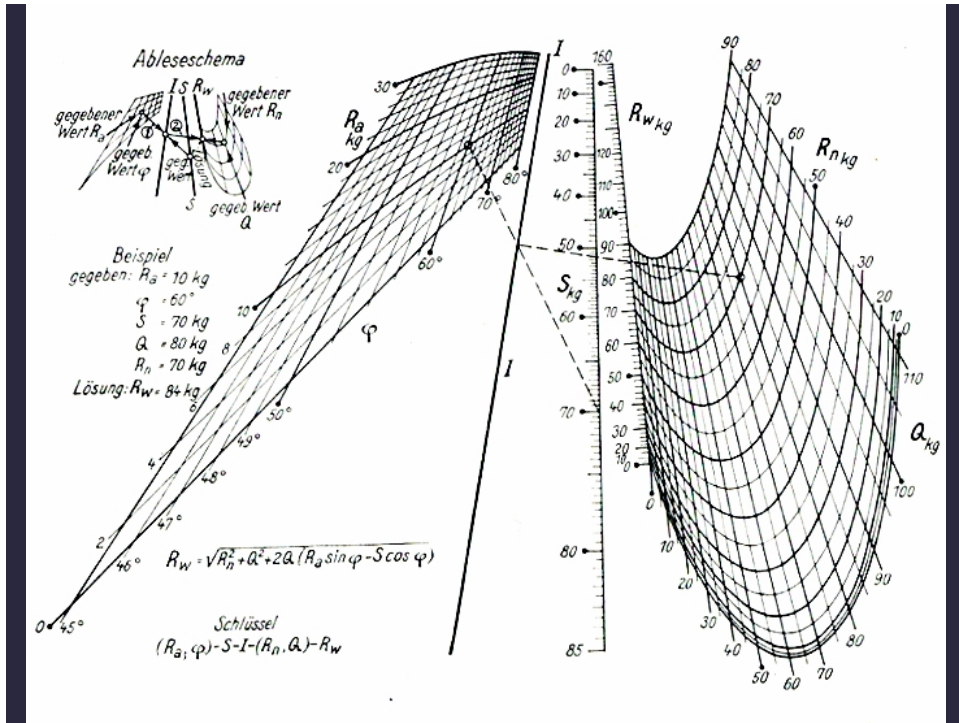
Lambert's graphical construction
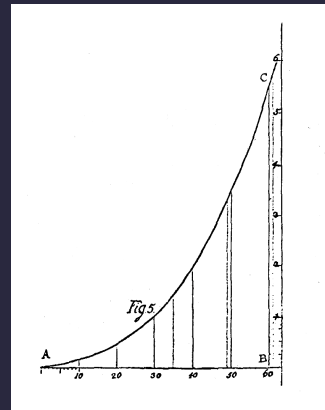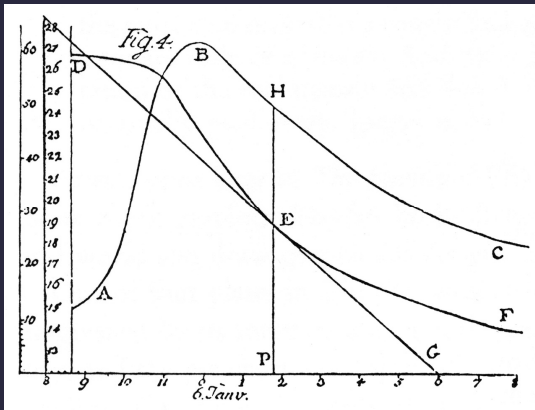
Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]

E. J. Marey, *La Méthode Graphique* (Paris, 1885), p. 20. The method is attributed to the French engineer, Ibry.

Reorderable Spaces

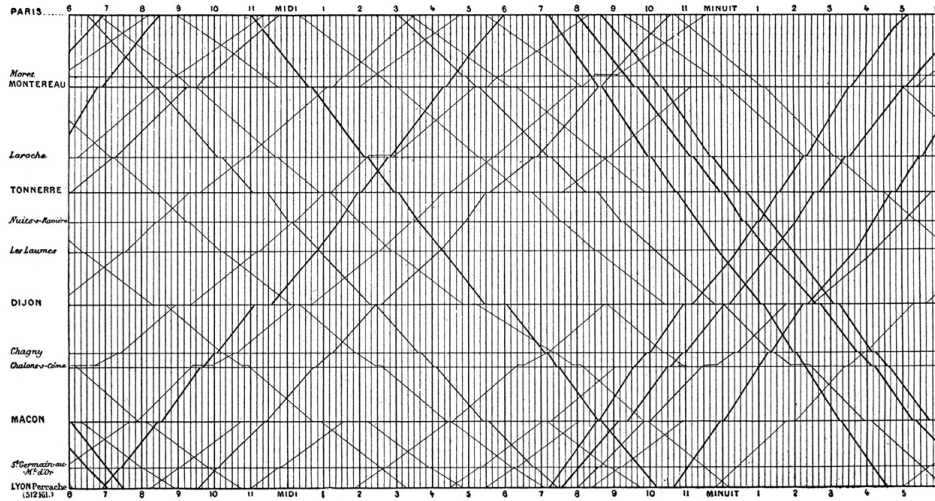| J	F	M	A	M	J	J	A	S	O	N	D		
26	21	26	28	20	20	20	20	20	40	15	40	1	% CLIENTELE FEMALE
69	70	77	71	37	36	39	39	55	60	68	72	2	% —"— LOCAL
7	6	3	6	23	14	19	14	9	6	8	8	3	% —"— U.S.A.
0	0	0	0	8	6	6	4	2	12	0	0	4	% —"— SOUTH AMERICA
20	15	14	15	23	27	22	30	27	19	19	17	5	% —"— EUROPE
1	0	0	8	6	4	6	4	2	1	0	1	6	% —"— M.EAST, AFRICA
3	10	6	0	3	13	8	9	5	2	5	2	7	% —"— ASIA
78	80	85	86	85	87	70	76	87	85	87	80	8	% BUSINESSMEN
22	20	15	14	15	13	30	24	13	15	13	20	9	% TOURISTS
70	70	75	74	69	68	74	75	68	68	64	75	10	% DIRECT RESERVATIONS
20	18	19	17	27	27	19	19	26	27	21	15	11	% AGENCY —"—
10	12	6	9	4	5	7	6	6	5	15	10	12	% AIR CREWS
2	2	4	2	2	1	1	2	2	4	2	5	13	% CLIENTS UNDER 20 YEARS
25	27	37	35	25	25	27	28	24	30	24	30	14	% —"— 20-35 —"—
48	49	42	48	54	55	53	57	55	46	55	43	15	% —"— 35-55 —"—
25	22	17	15	19	19	19	19	19	20	19	22	16	% —"— MORE THAN 55 —"—
163	167	166	174	152	155	145	170	157	174	165	156	17	PRICE OF ROOMS
1.65	1.71	1.65	1.91	1.90	2.	1.54	1.60	1.73	1.82	1.66	1.44	18	LENGTH OF STAY
67	82	70	83	74	77	56	62	90	92	78	55	19	% OCCUPANCY
		×	×	×			×	×	×	×		20	CONVENTIONS

[Graphics and Graphic Information Processing, Bertin 81]
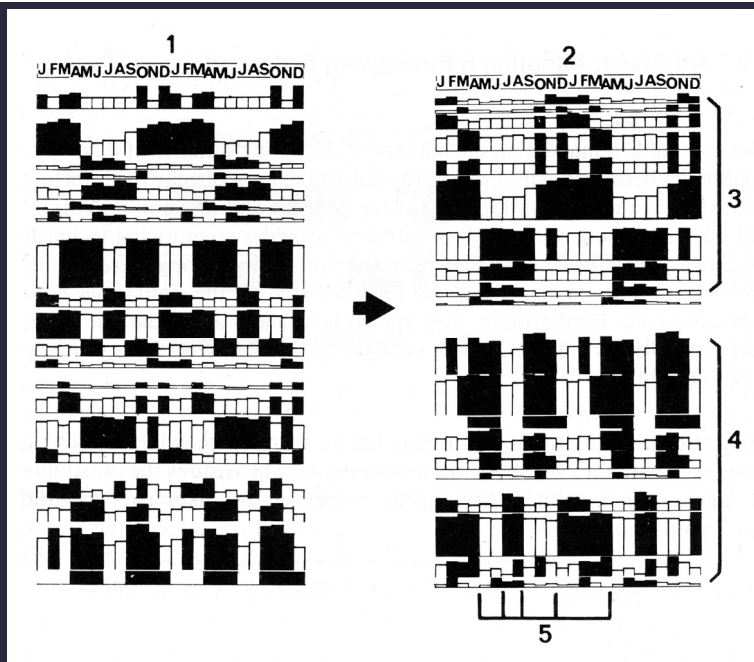
[Graphics and Graphic Information Processing, Bertin 81]
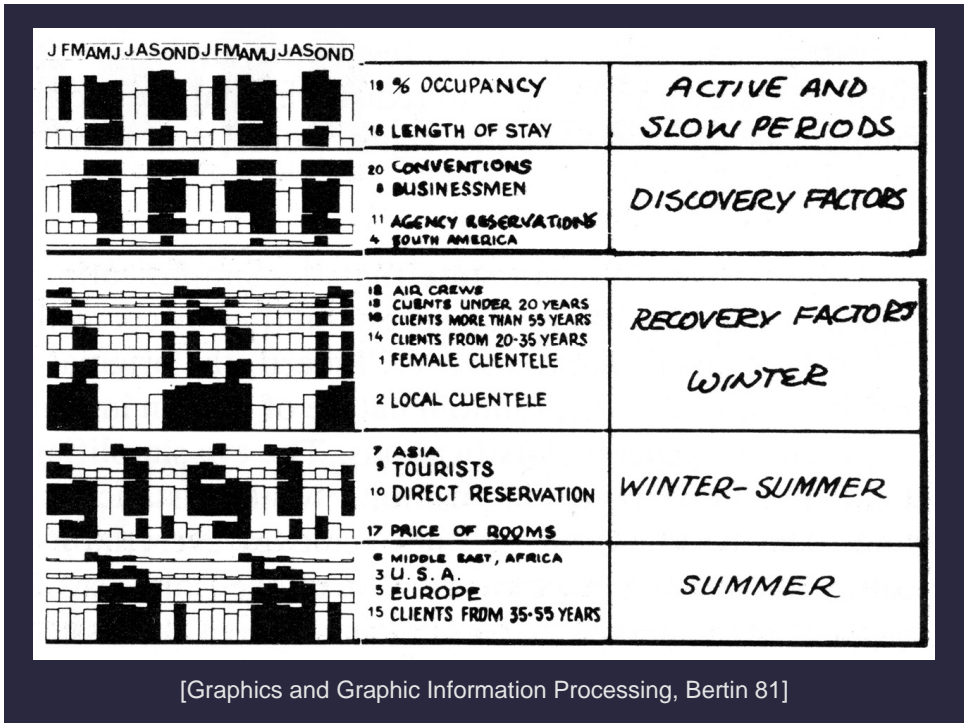
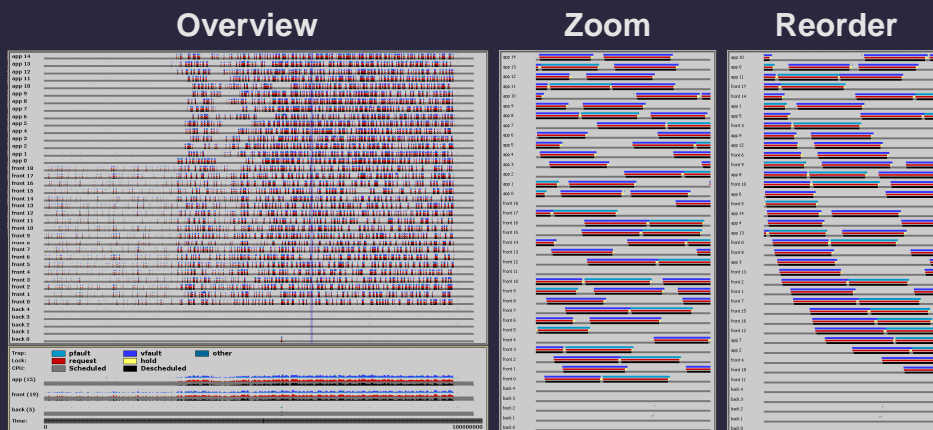[Graphics and Graphic Information Processing, Bertin 81]
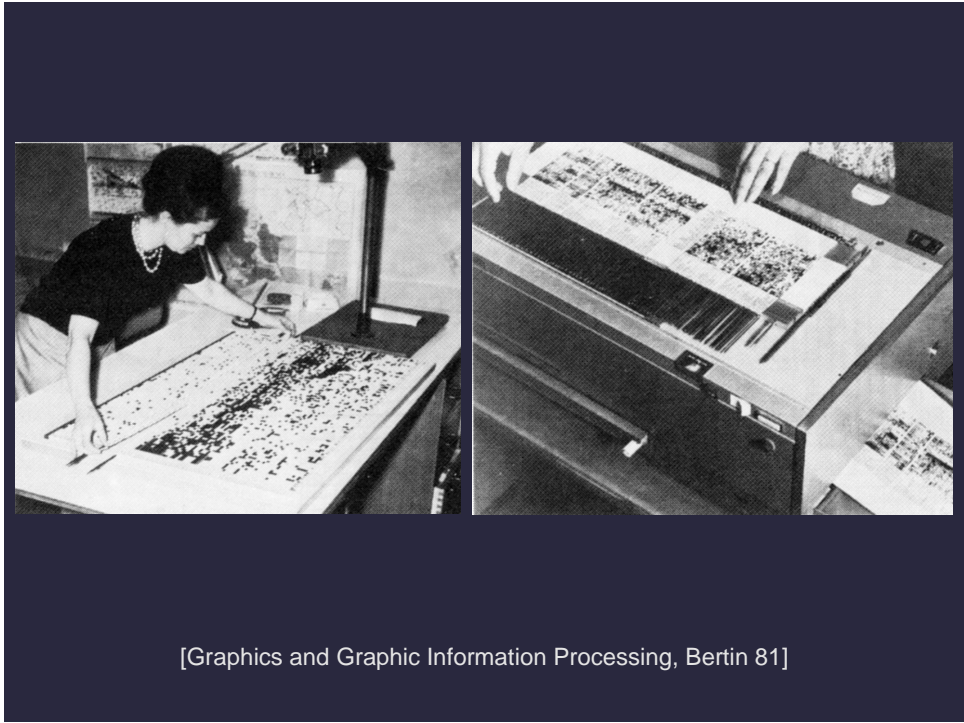
[Graphics and Graphic Information Processing, Bertin 81]

[Graphics and Graphic Information Processing, Bertin 81]

Rivet: Interactive reordering

Overview   **Zoom**   **Reorder**

Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study [Bosch et al. 00]

Trellis
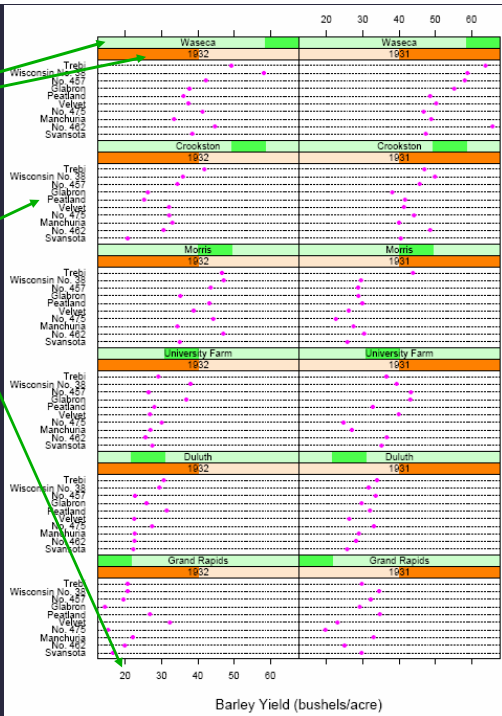[Becker, Cleveland, and Shyu 96]
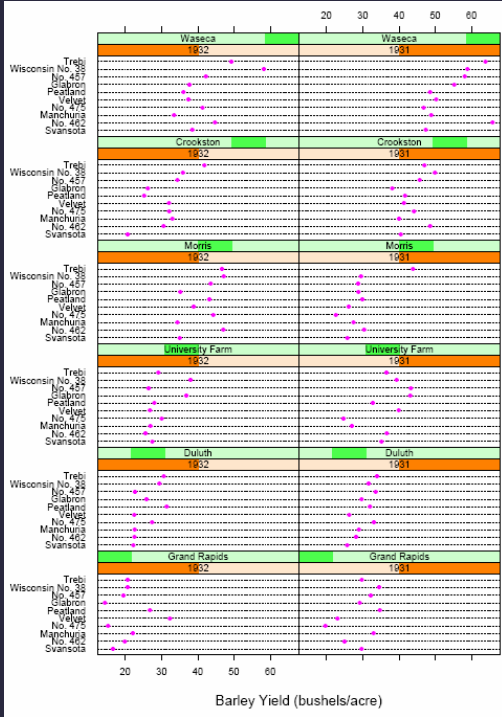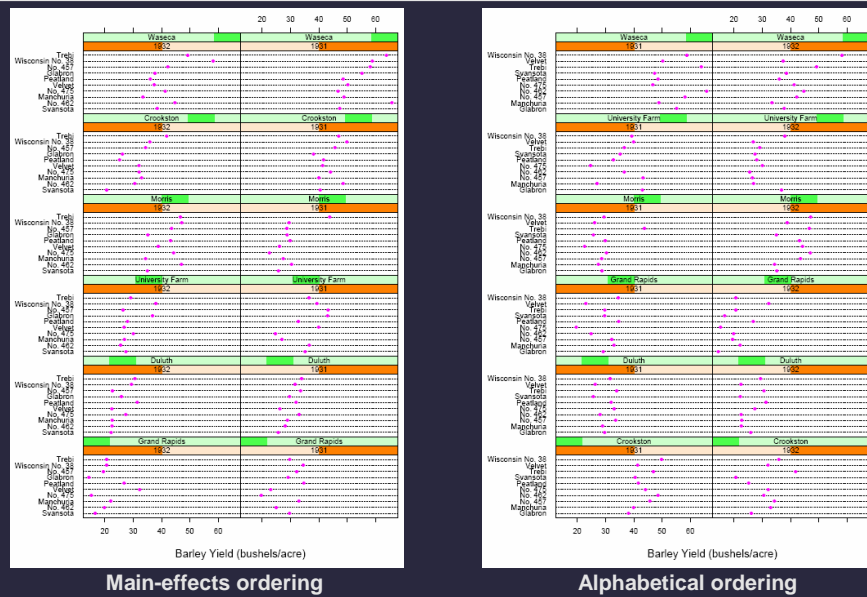
Condition variables
location, year

Panel variables
type, yield

Trellis
[Becker, Cleveland, and Shyu 96]

34

Trellis: Automatic ordering

Main-effects ordering   Alphabetical ordering

Summary

- **Spatial layout is the most important visual encoding**
- **Geometric invariants of spatial transformations support geometric reasoning**
- **Use distortions to emphasize important information**
- **Use space to show data with as much resolution as possible**
- **Ordering is a powerful operation for organizing the data**