Space

Pat Hanrahan

On Being the Right Size

"The most obvious differences between different animals are differences of size, but for some reason zoologists have paid singularly little attention to them. In a large textbook of zoology before me I find no indication that the eagle is larger than the sparrow, or the hippopotamus bigger than the hare, though some grudging admissions are made in the case of the mouse and the whale. But yet it is easy to show that the hare could not be as large as a hippopotamus, or a whale as small as a herring. For every type of animal there is a most convenient size, and a large change in size inevitably carries with it a change of form"

J. B. S. Haldane

On Being the in the Right Space

"The most obvious differences between different visualizations are differences of space, but for some reason visualization scientists have paid singularly little attention to them. In a large textbook of visualization before me I find no indication that the log-log space is different than the log-linear space, or that the mercator projection is different than the azimuthal equidistant projection, though some grudging admissions are made in the case of the parallel and perspective projections. But yet it is easy to show that distances are difficult to estimate under perspective, or that data obeying a power law is easy to see in a log-log plot. For every type of visualization there is a most convenient space, and a change into the right space inevitably makes relationships clearer."

P. Hanrahan

Topics

Cartographic projections and distortion

Graphs and lines

Phase spaces

Reorderable spaces

Cartographic Projections

Lattitude-Longitude Projection

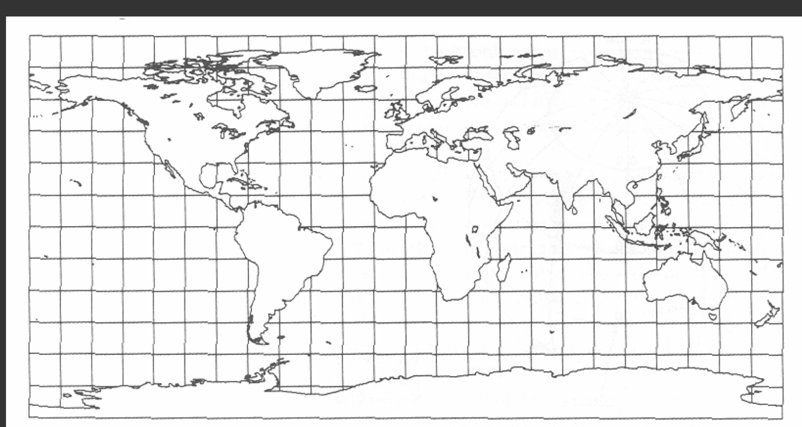


Figure 1.3, *Flattening the Earth*, Snyder

Azimuthal Equidistance

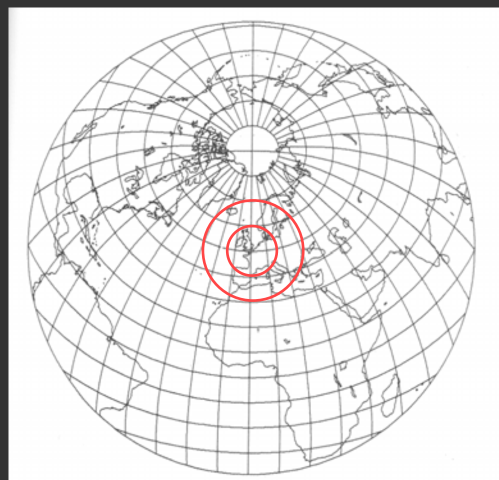


Figure 3.4, *Flattening the Earth*, Snyder

Equi-Heading - Mercator

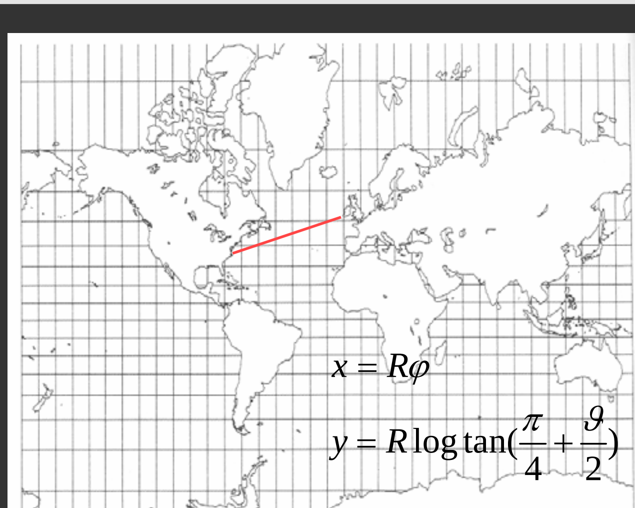


Figure 1.35, *Flattening the Earth*, Snyder

Sinusoidal Equiareal Projection

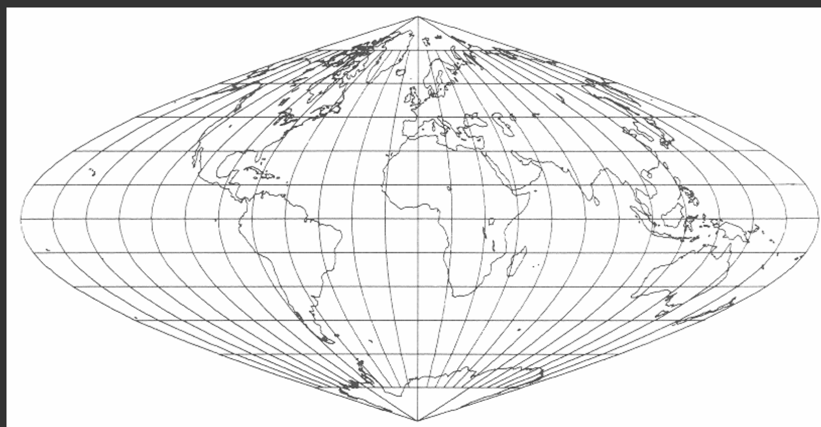
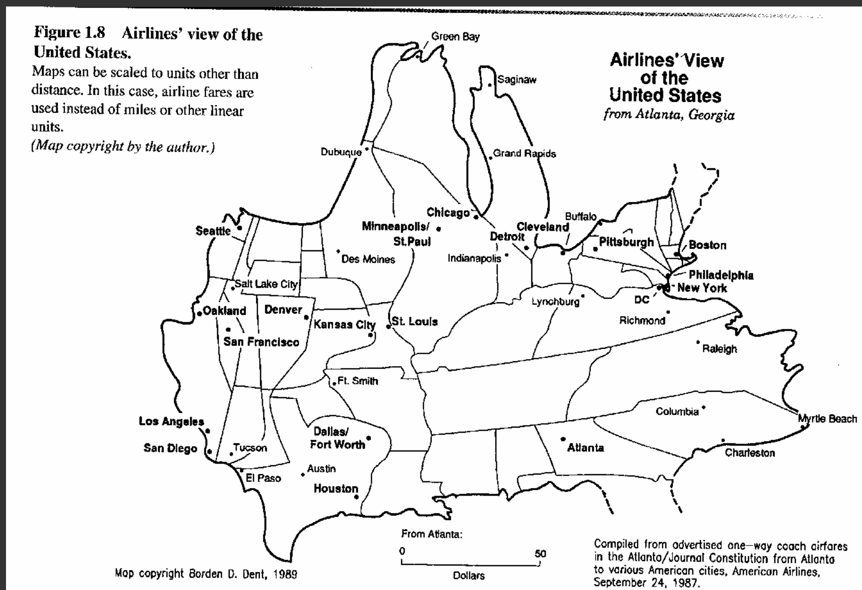


Figure 1.39a, *Flattening the Earth*, Snyder

Mercator Projection of Mars

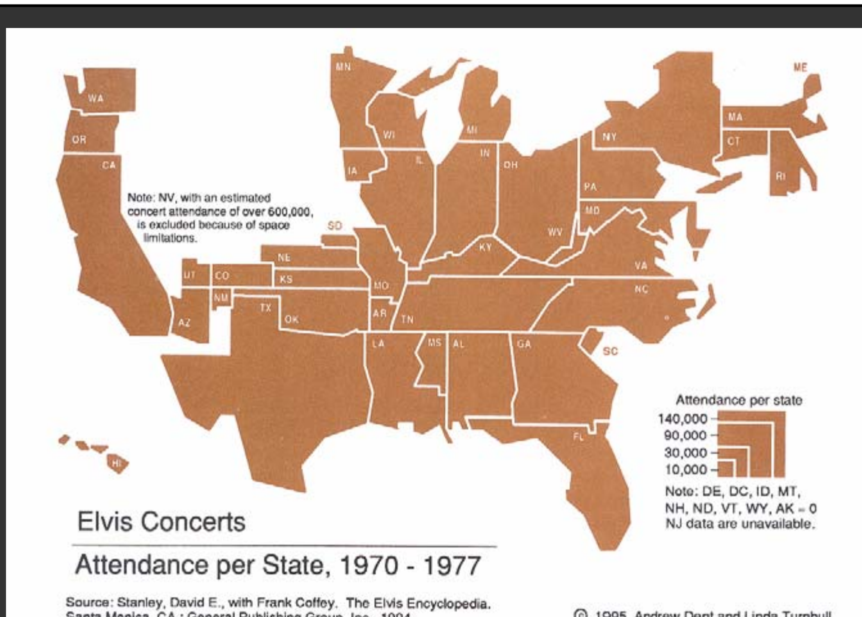
Circular craters map to circles

http://astrogeology.usgs.gov/Gallery/MapsAndGlobes/mars.html#MarsMOLAContourMap



Scale Distance by Data

From *Cartography*, Dent

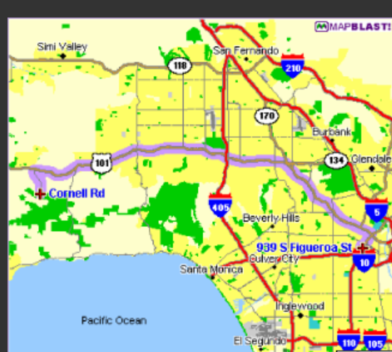


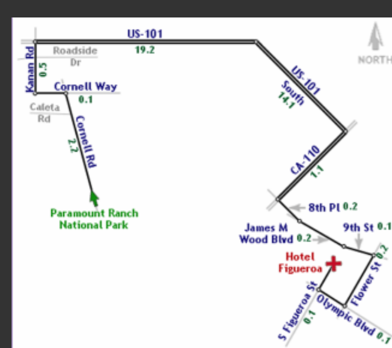
Scale Area by Data

From *Cartography*, Dent

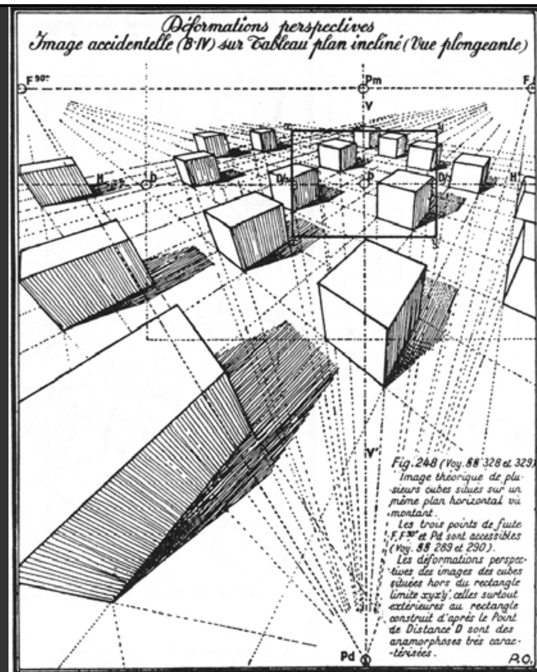
http://www.thetube.com/content/history/map.asp

Route Maps [Agrawala & Stolte]





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

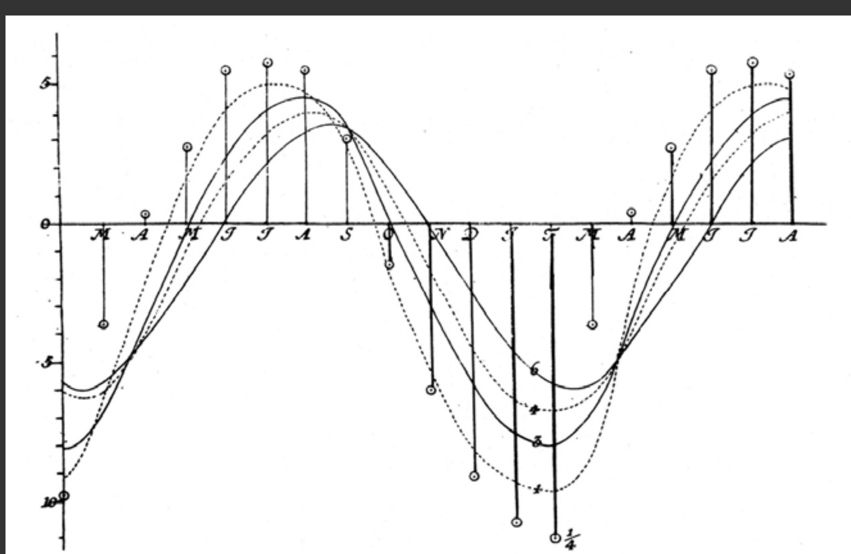


Marginal distortions, Olmer [From Kubovy, f. 7.2, p. 106]

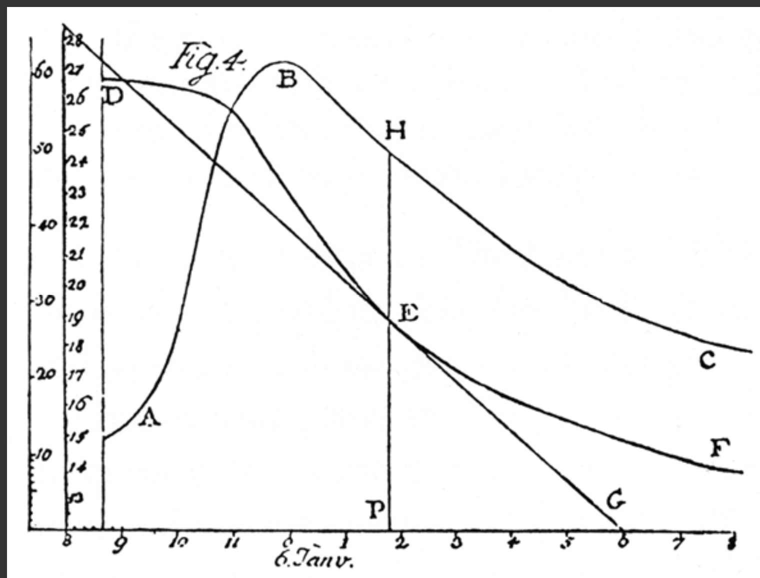
Issues

- Choose coordinate systems that support geometric reasoning
  - Anamorphosis: Maps features to lines
- Tension between geometric properties
  - Equiarea implies not equiangular
- People tolerate distortion -- to an extent
  - Maintain important information
  - Avoid extremes

Graphs and Lines



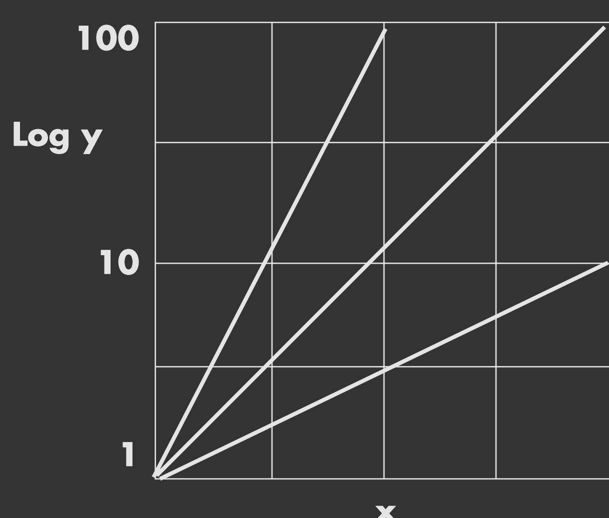
Johannes Lambert – 1765 [From Tilling]



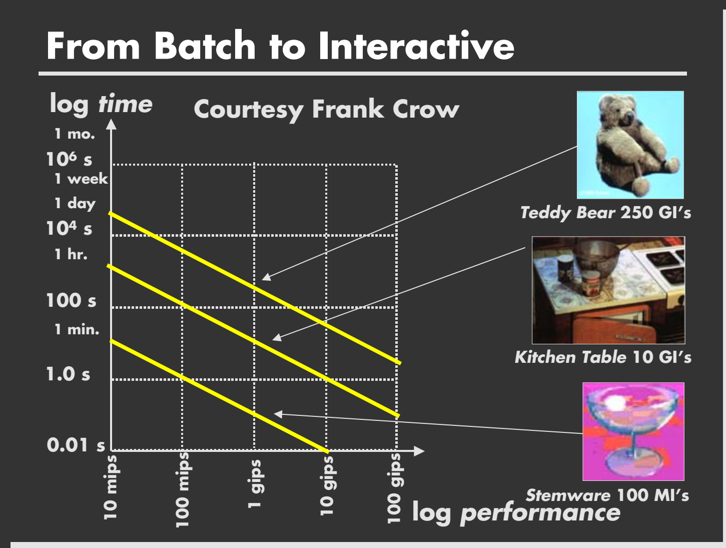
Johannes Lambert – 1765 [From Tilling]

log y = log a + x log b

Power Laws e.g. Stevens Power Laws



log P = log x + log y



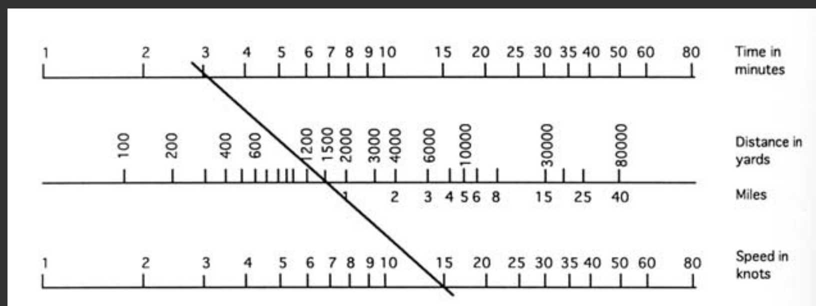
Anamorphosis

Tukey and Mosteller's pictures of power laws

Straightening out data

Best power law regression

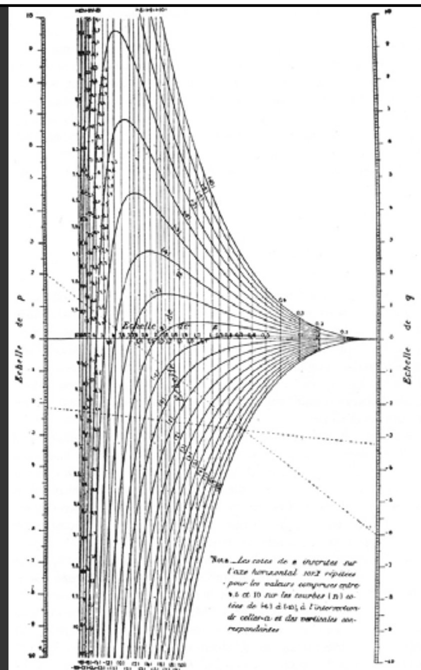
Nomograms



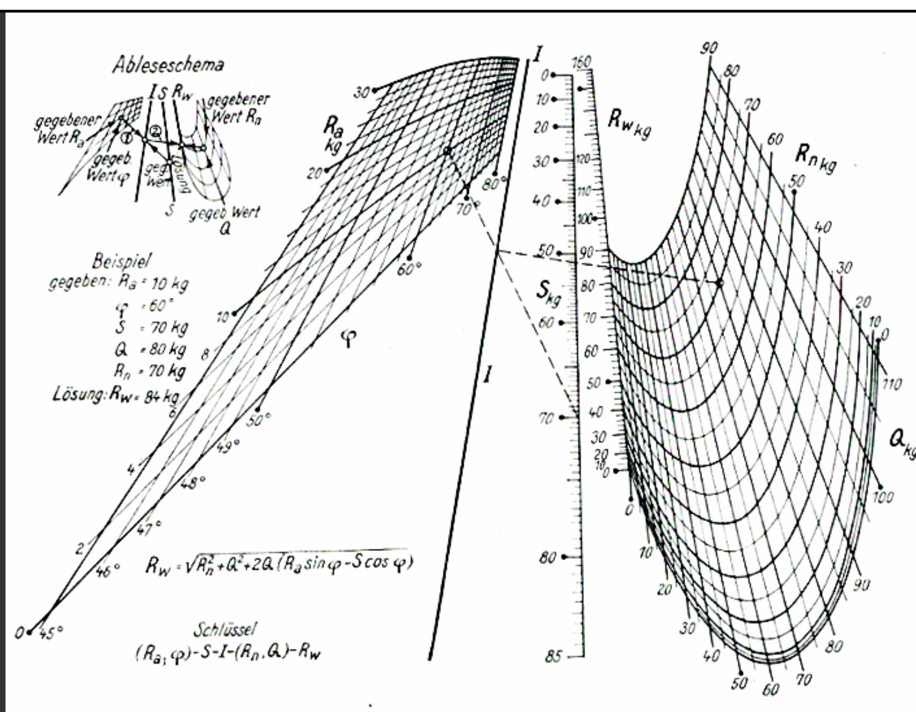
The Rule of Three

Theory

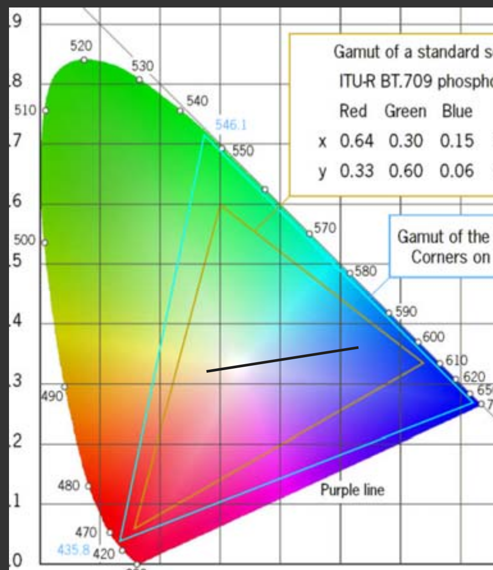
$$\begin{vmatrix} x_1(u) & y_1(u) & w_1(u) \\ x_2(v) & y_2(v) & w_2(v) \\ x_3(s,t) & y_3(s,t) & w_3(s,t) \end{vmatrix} = 0$$



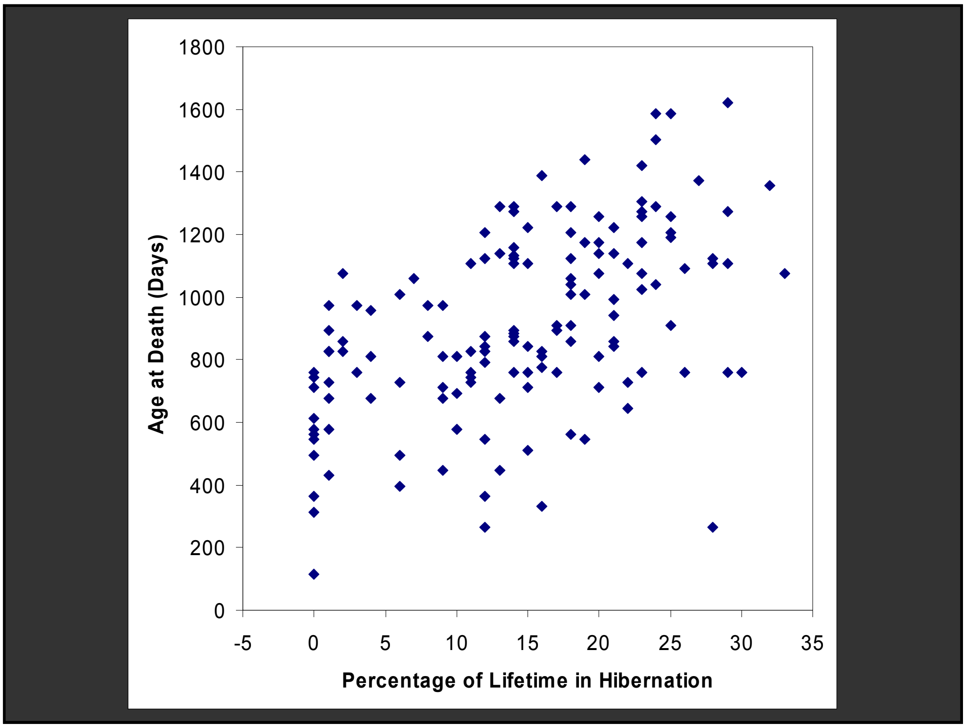
From O’cagne, Le Calculi Simplifie

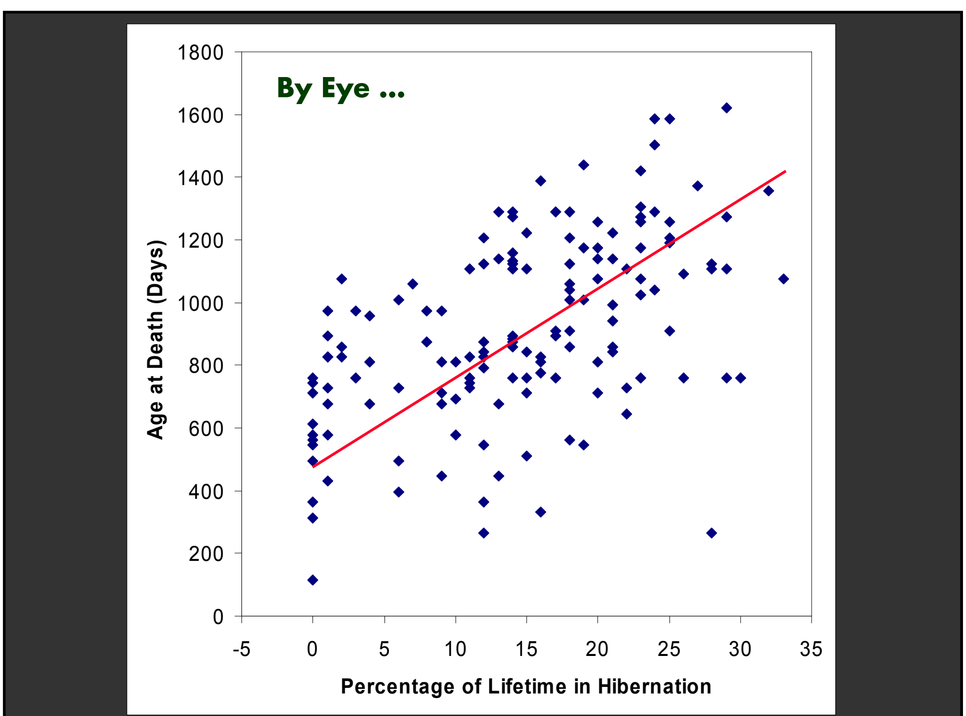


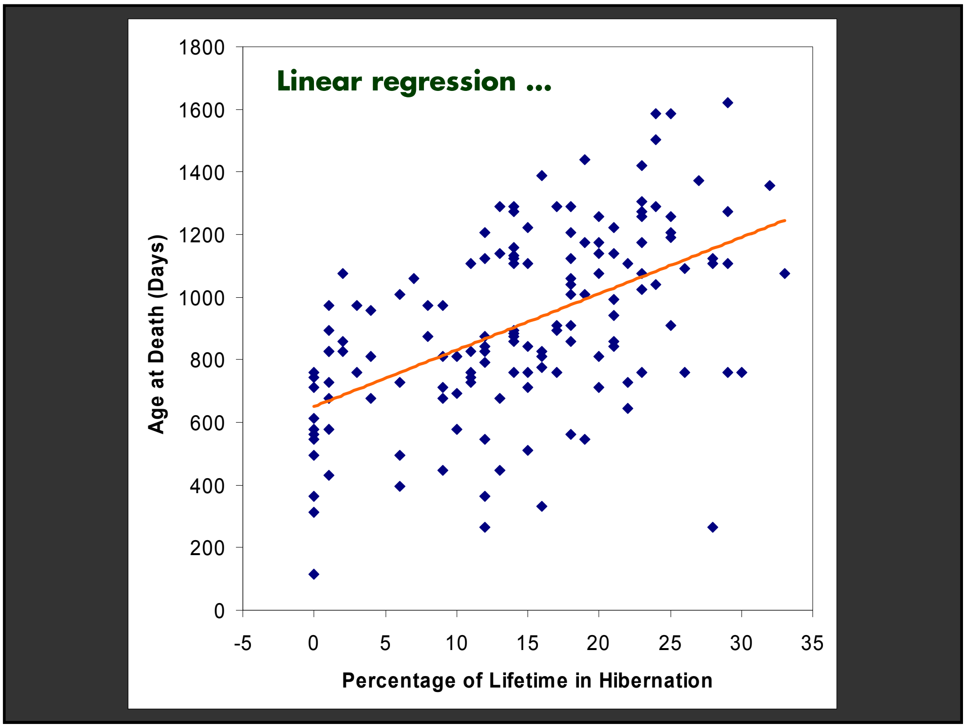
3D Lines Project to 2D lines

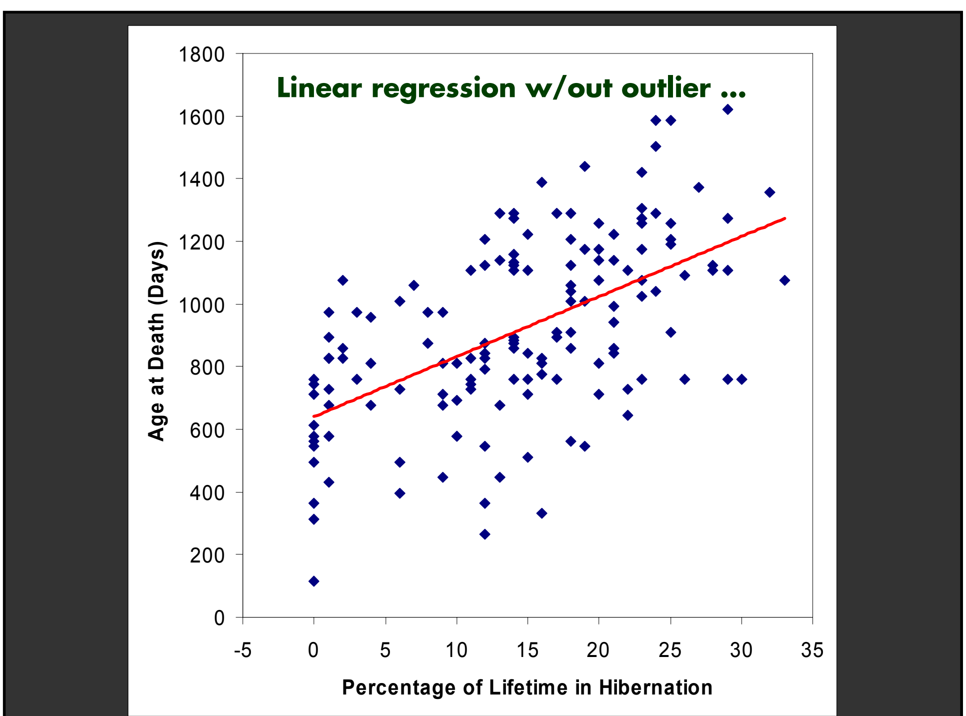


Perception of Lines


1800
1600
1400
1200
1000
800
600
400
200
0
-5
0
5
10
15
20
25
30
35
Age at Death (Days)
Percentage of Lifetime in Hibernation

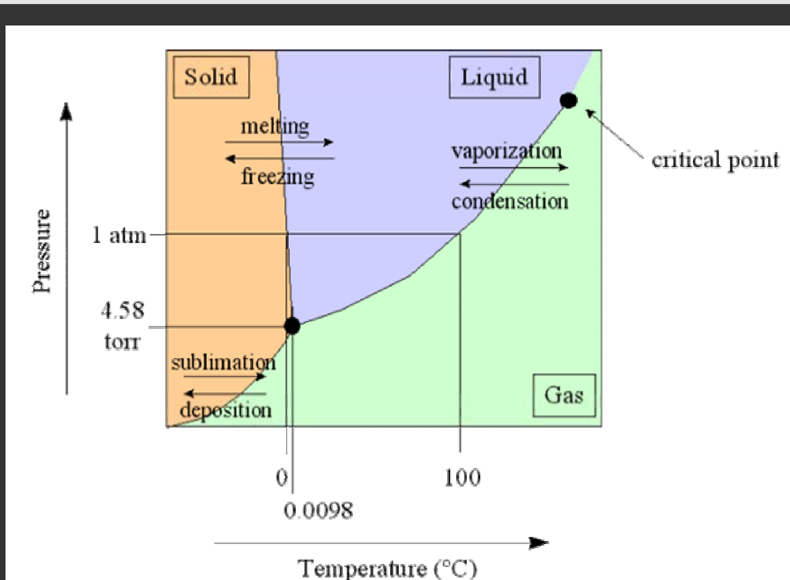

By Eye ...
1800
1600
1400
1200
1000
800
600
400
200
0
-5
0
5
10
15
20
25
30
35
Age at Death (Days)
Percentage of Lifetime in Hibernation


Linear regression ...
Age at Death (Days)
Percentage of Lifetime in Hibernation
1800
1600
1400
1200
1000
800
600
400
200
0
-5
0
5
10
15
20
25
30
35


Linear regression w/out outlier ...
Age at Death (Days)
Percentage of Lifetime in Hibernation
1800
1600
1400
1200
1000
800
600
400
200
0
-5
0
5
10
15
20
25
30
35

Phase Spaces

H_20 Phase Diagram



Cubic Filters

Mitchell Cubic Filter

$$h(x) \;\; \frac{1}{6} \begin{array}{ll} (12 \;\; 9B \;\; 6C)x^3 \;\; (\;\; 18 \;\; 12B \;\; 6C)x^2 \;\; (6 \;\; 2B) & |x| \;\; 1 \\ (\;\; B \;\; 6C)x^3 \;\; (6B \;\; 30C)x^2 \;\; (\;\; 12B \;\; 48C)x \;\; (8B \;\; 24C) & 1 \;\; |x| \;\; 2 \\ 0 & otherwise \end{array}$$

Properties:

$$\underset{n}{\overset{n}{}} \; h(x) \;\; 1$$

B parame

1/3)

B-spline: $(1,0)$

Catmull-Rom: $(0,1/2)$

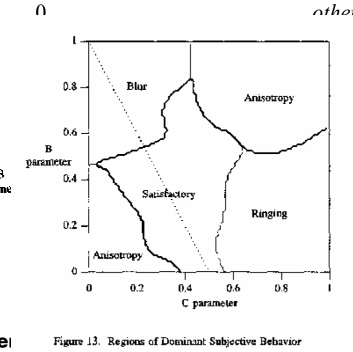
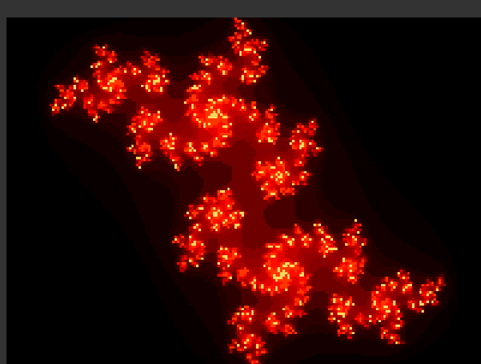


Figure 13. Regions of Dominant Subjective Behavior

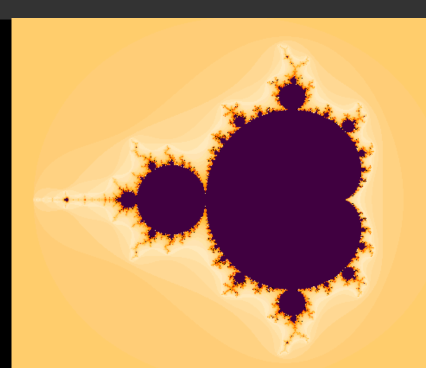
From Mitchell and Netravali
Look at other figures in that paper

CS348B Lecture 7 **Pat Hanrahan, Spring 2001**

Julia and Mandelbrot Sets



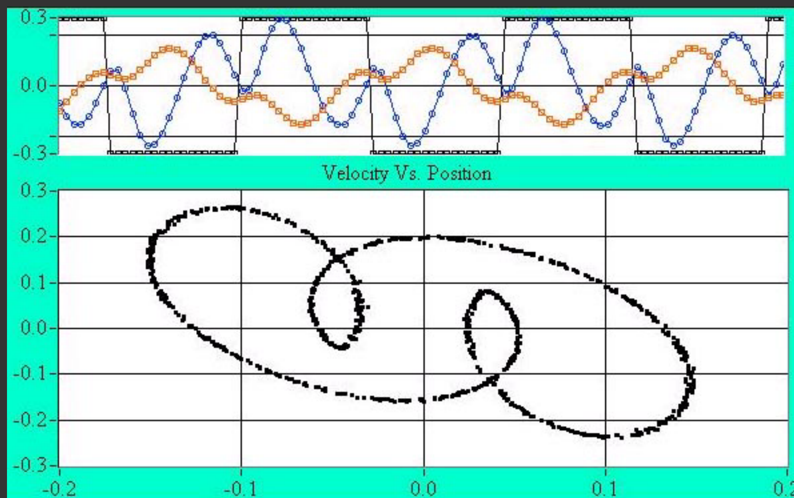
Julia Set



Mandelbrot Set

$$z^2 \leftarrow z^2 + c$$

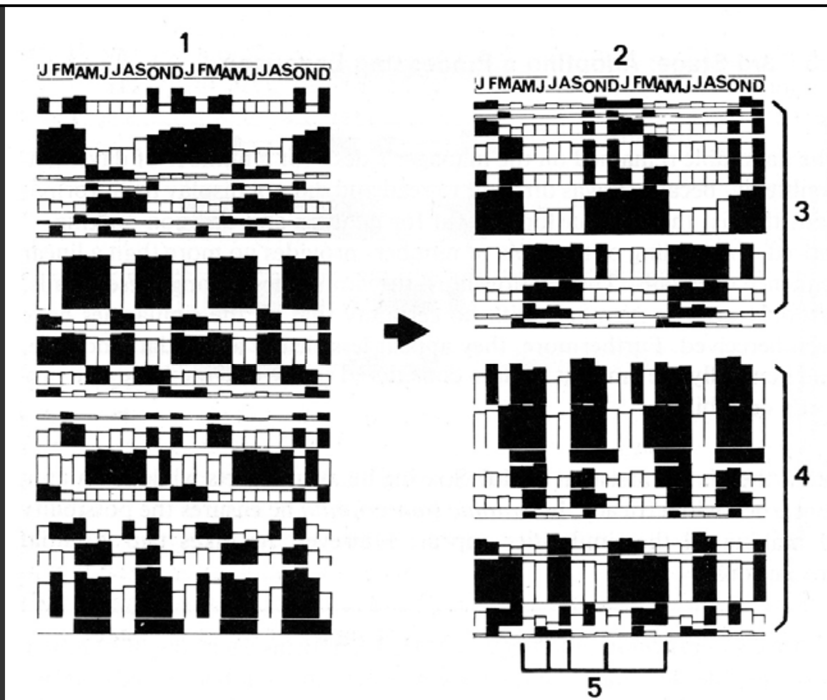
Poincare Phase Space

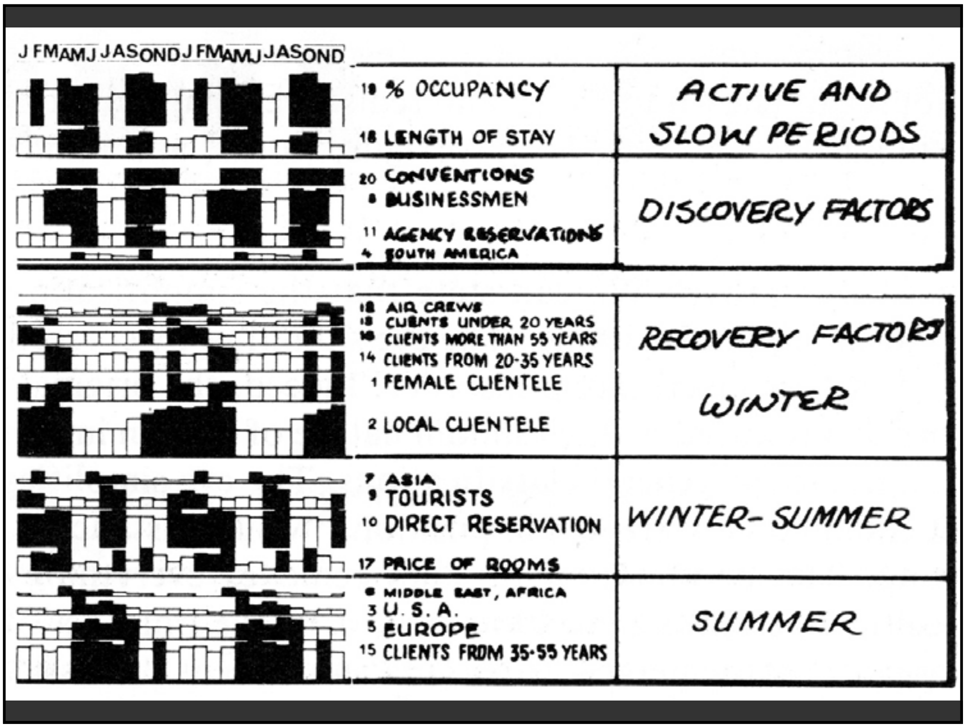


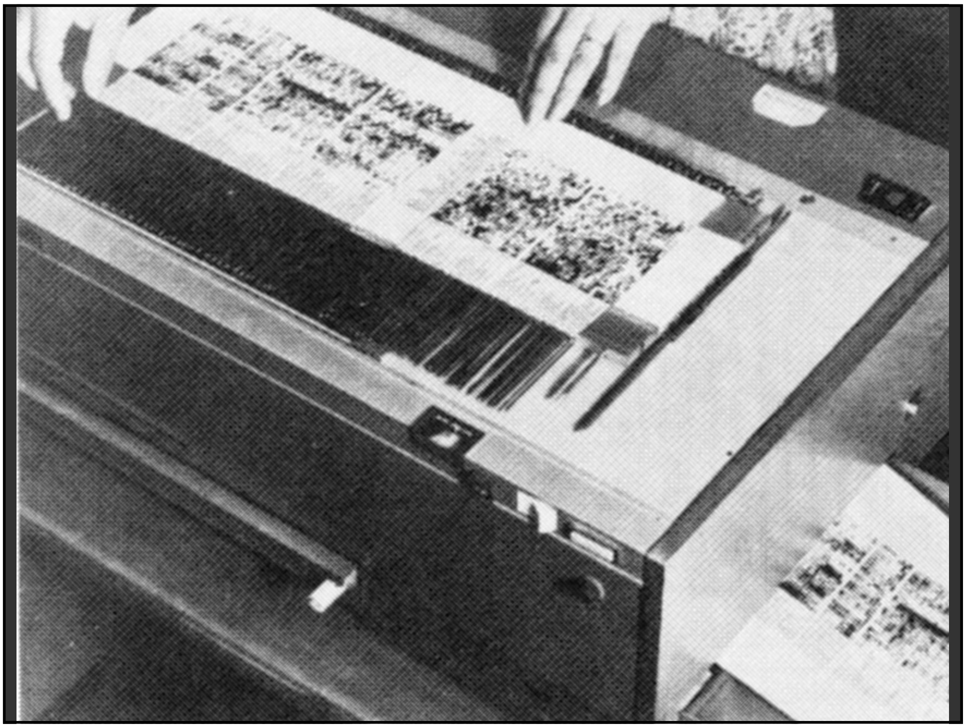
Reorderable Spaces

[From Bertin]

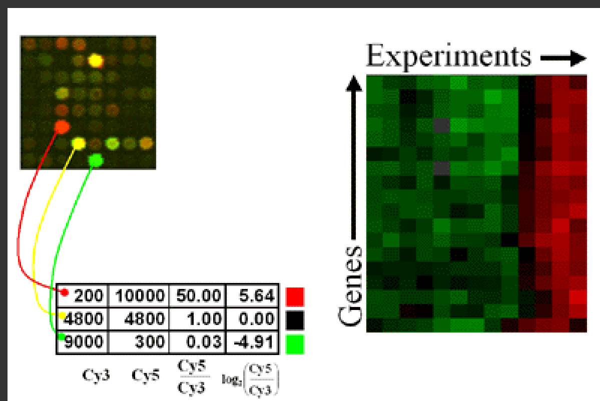
J	F	M	A	M	J	J	A	S	O	N	D		
26	21	26	28	20	20	20	20	20	40	15	40	1	% CLIENTELE FEMALE
69	70	77	71	37	36	39	39	55	60	68	72	2	% —"— LOCAL
7	6	3	6	23	14	19	14	9	6	8	8	3	% —"— U.S.A.
0	0	0	0	8	6	6	4	2	12	0	0	4	% —"— SOUTH AMERICA
20	15	14	15	23	27	22	30	27	19	19	17	5	% —"— EUROPE
1	0	0	8	6	4	6	4	2	1	0	1	6	% —"— 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	51	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
			X	X	X			X	X	X	X	20	CONVENTIONS




J F M A M J J A S O N D J F M A M J J A S O N D
19 % OCCUPANCY
18 LENGTH OF STAY
ACTIVE AND SLOW PERIODS
20 CONVENTIONS
8 BUSINESSMEN
11 AGENCY RESERVATIONS
4 SOUTH AMERICA
DISCOVERY FACTORS
12 AIR CREWS
13 CLIENTS UNDER 20 YEARS
16 CLIENTS MORE THAN 55 YEARS
14 CLIENTS FROM 20-35 YEARS
1 FEMALE CLIENTELE
2 LOCAL CLIENTELE
RECOVERY FACTORS
WINTER
7 ASIA
9 TOURISTS
10 DIRECT RESERVATION
17 PRICE OF ROOMS
WINTER-SUMMER
6 MIDDLE EAST, AFRICA
3 U.S.A.
5 EUROPE
15 CLIENTS FROM 35-55 YEARS
SUMMER



Clustering Gene Expression



Nested Spaces

Barley Data and the Trellis

		Glabron	Manchuria	No. 457	No. 462	No. 475	Peatland	Svansota	Trebi	Velvet	Wisconsin No.
Crookston	1931	38	40	46	49	44	42	40	47	41	50
	1932	26	33	34	31	32	25	21	42	32	36
Duluth	1931	30	29	34	28	33	32	26	34	26	32
	1932	26	23	23	23	27	31	22	31	22	29
Grand Rapids	1931	29	33	32	25	20	35	30	30	23	34
	1932	14	22	19	20	15	27	17	21	32	21
Morris	1931	29	27	29	30	23	30	26	44	26	29
	1932	35	34	44	47	44	43	35	47	39	47
University Farm	1931	43	27	43	37	25	33	35	37	40	39
	1932	37	27	26	26	30	28	27	29	27	38
Waseca	1931	55	49	58	66	47	49	47	64	50	59
	1932	38	33	42	45	41	36	39	49	37	58

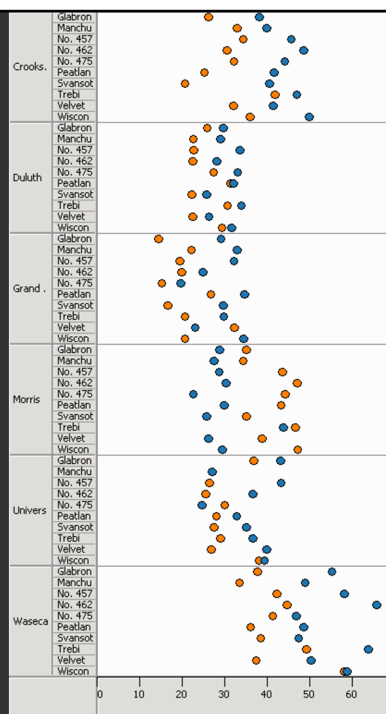
Yields per plot are measured

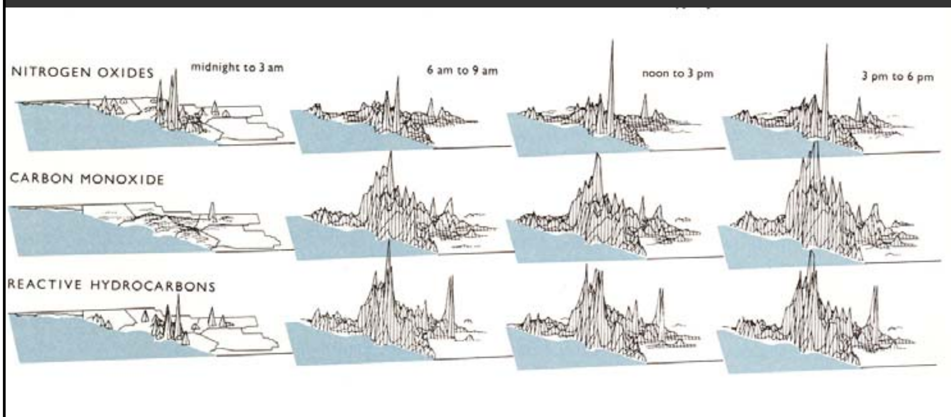
6 Sites = {Crookstein, Duluth, Grand Rapids, Morris, University Farm, Waseca}

8 Varieties = {Glabron, Manchuria, No. 457, No. 462, No. 475, Peatland, Swansota, Trebi, Velvet, Wisconsin No. 38

2 Years = {1931, 1932}

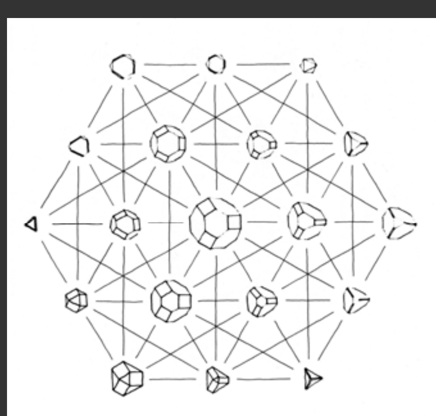
Example from Cleveland

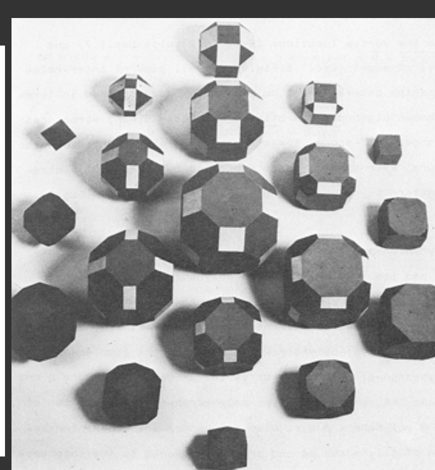




G. J. MacRae, W. R. Goodin, J. H. Seinfeld [Redrawn by E. Tufte]

The Space of Polyhedra





Haresh Lalvani

Wrap-Up

Summary

On being in the right space

Spatial encoding the most important encoding

Geometric invariants of spatial transformations support geometric reasoning

"Linear" reasoning

The good and bad of distortion

Graphs and abstract spaces recent invention