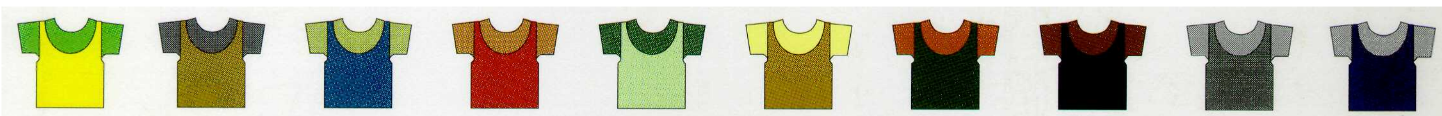
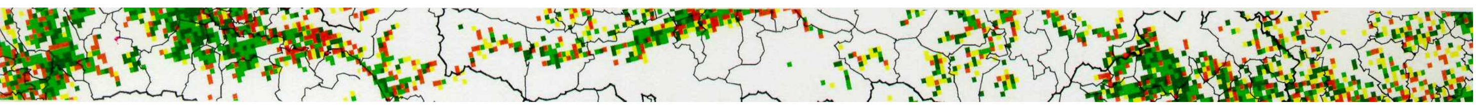
Edward R. Tufte

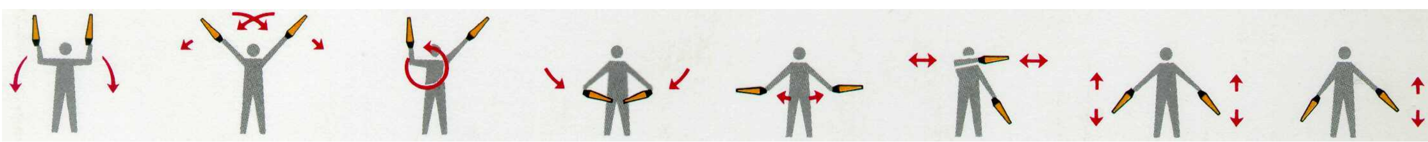
Envisioning Information



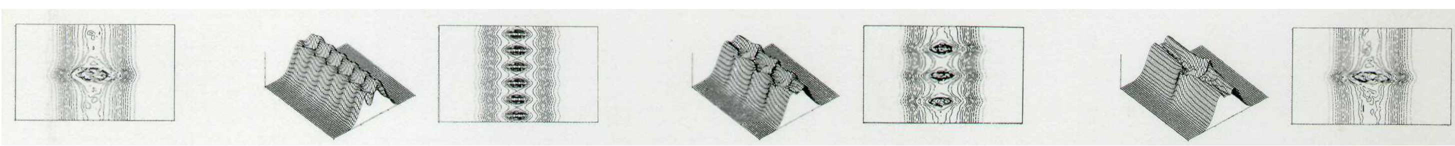
ESCAPING FLATLAND



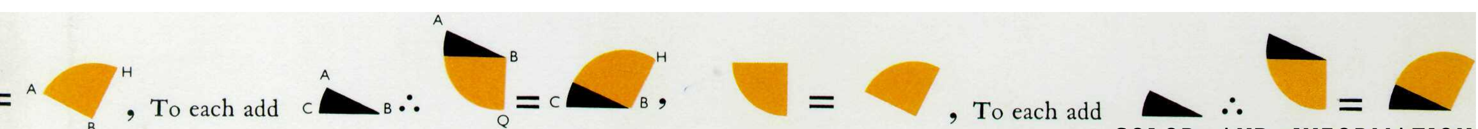
MICRO/MACRO READINGS



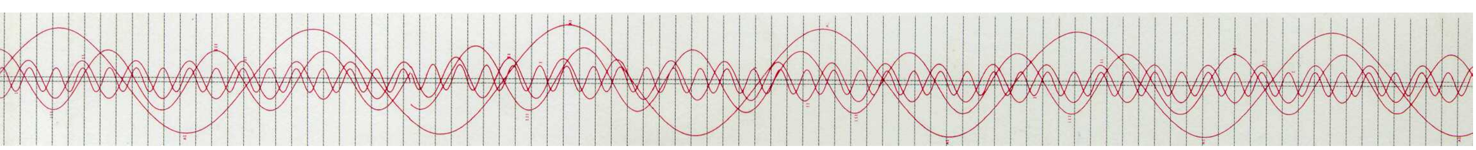
LAYERING AND SEPARATION



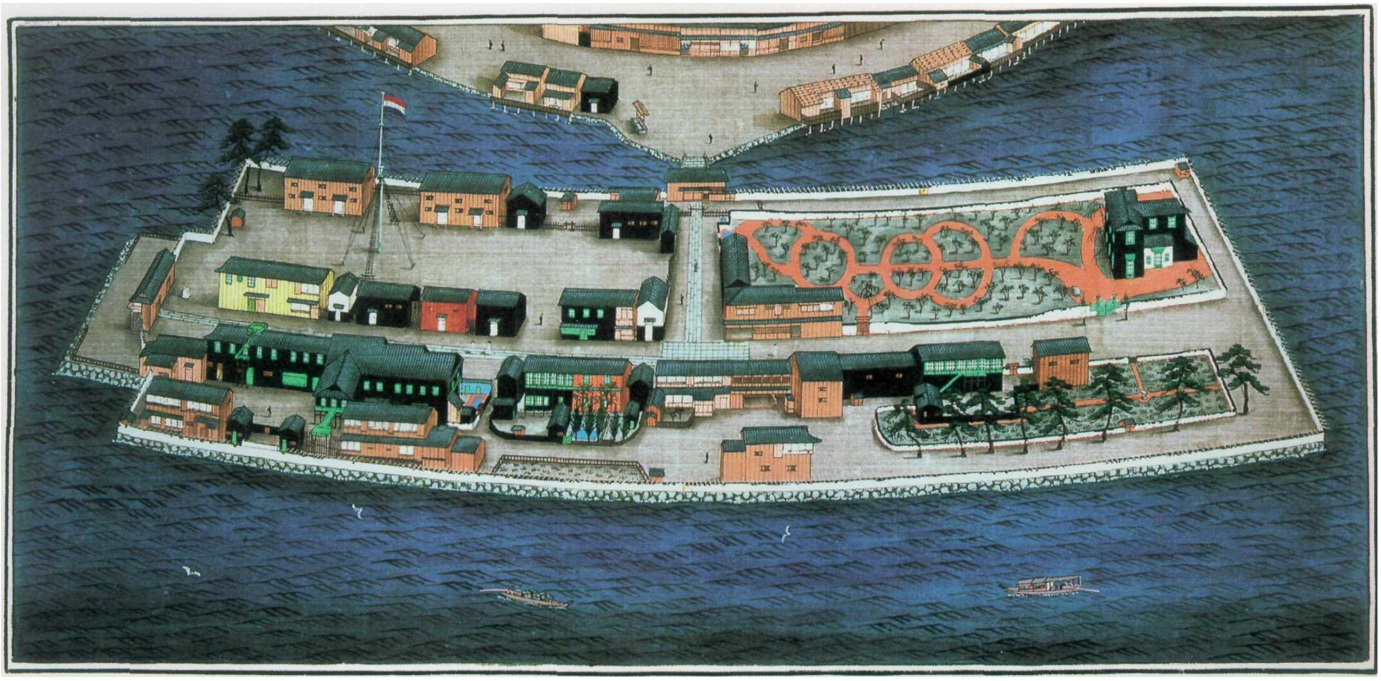
SMALL MULTIPLES



COLOR AND INFORMATION



NARRATIVES OF SPACE AND TIME



Two paintings on silk depicting Dejima Island, a view from the Bay (top), a view from Nagasaki (bottom), circa 1860.

Edward R. Tufte

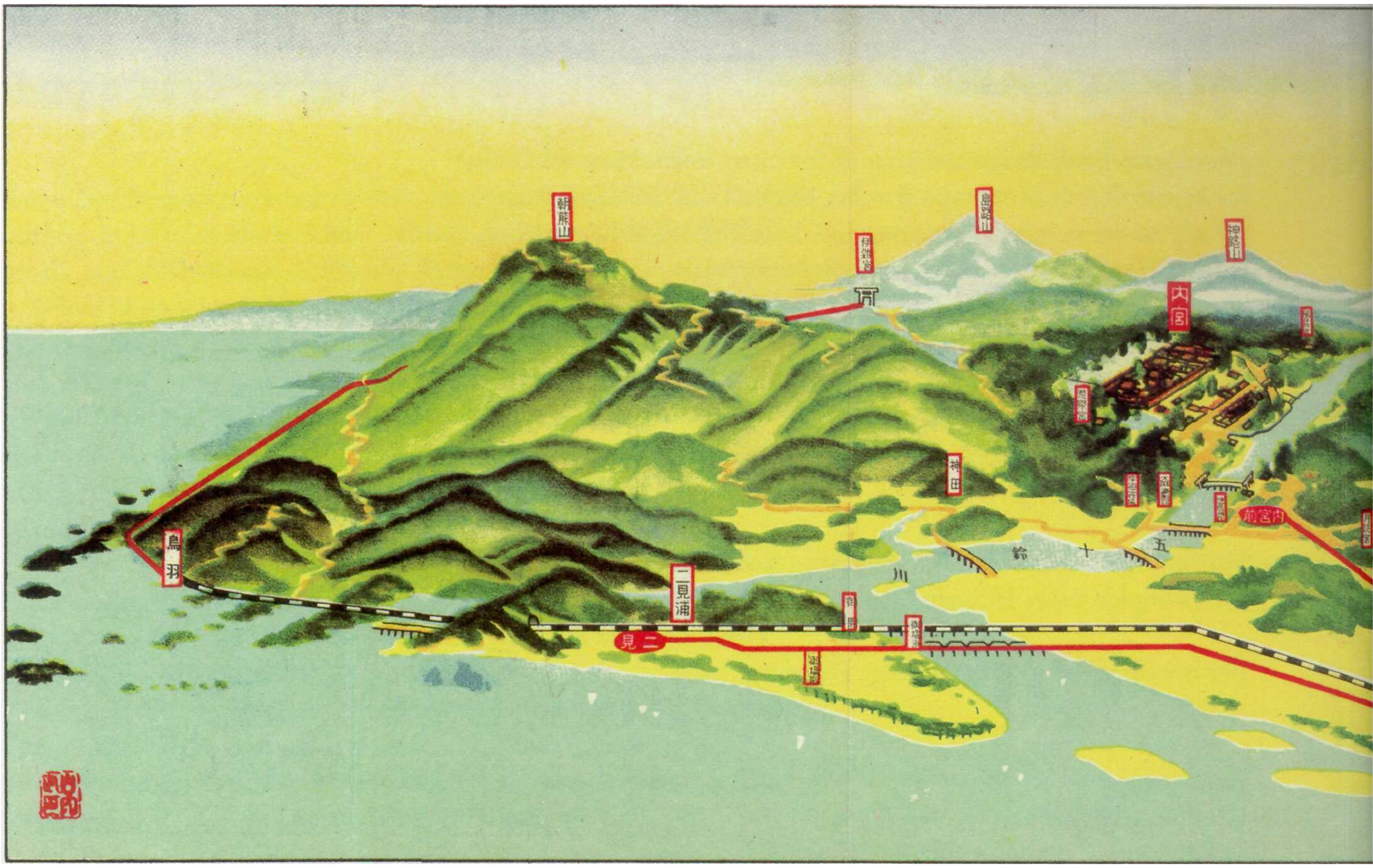
Envisioning Information

Graphics Press • Cheshire, Connecticut

1 Escaping Flatland

EVEN though we navigate daily through a perceptual world of three spatial dimensions and reason occasionally about higher dimensional arenas with mathematical ease, the world portrayed on our information displays is caught up in the two-dimensionality of the endless flatlands of paper and video screen.[1] All communication between the readers of an image and the makers of an image must now take place on a two-dimensional surface. *Escaping this flatland is the essential task of envisioning information — for all the interesting worlds (physical, biological, imaginary, human) that we seek to understand are inevitably and happily multivariate in nature. Not flatlands.*

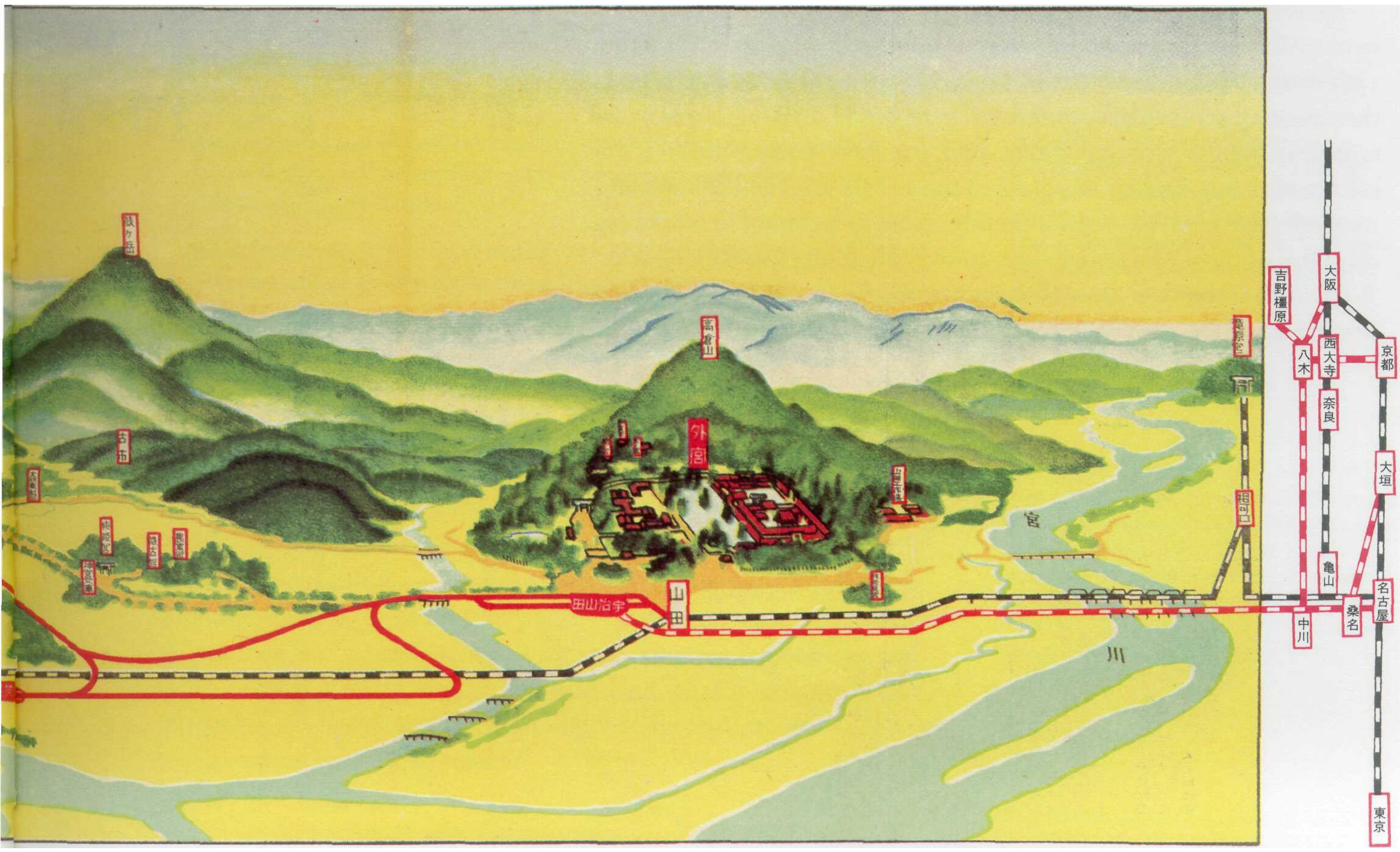
[1] The idea of "flatland" is based on the classic by A. Square [Edwin A. Abbott], *Flatland: A Romance of Many Dimensions* (London, 1884). A recent statement from an artist's viewpoint (How can modern painting, abstractionism, escape flatland?) is found in Frank Stella, *Working Space* (Cambridge, 1986).



THIS chapter outlines a variety of design strategies that sharpen the information resolution, the resolving power, of paper and video screen. In particular, these methods work to increase (1) the number of dimensions that can be represented on plane surfaces and (2) the data density (amount of information per unit area).

IN this Japanese travel guide, an engaging hybrid of design technique, the abrupt shift from friendly perspective to hard flatland shows the loss suffered by giving in to the arbitrary data-compression of paper surfaces. A bird's-eye view with detailed perspective describes local areas near the architecturally renowned Ise Shrine; then, on the right margin, a very flat map delineates the national railroad system linking the shrine to major cities, somewhat compensating for loss of a visual dimension with a broad overview. A change in design accommodates a change in the scale of the map, and local detail is shown in national context, a mixed landscape of refuge and overview. The horizontal layout combines harmoniously with the vertical orientation of the language, so that the stand-up labels point precisely to each location.

Guide for Visitors to Ise Shrine (Ise, Japan; no date; published between October 1948 and April 1954, according to The Library, Ise Shrine, Mie Prefecture).

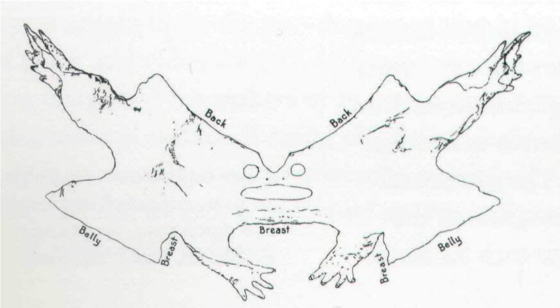


Mary C. Dickerson, *The Frog Book: North American Toads and Frogs, with a Study of the Habits and Life Histories of those of the Northeastern States* (New York, 1906), pp. 74-75.

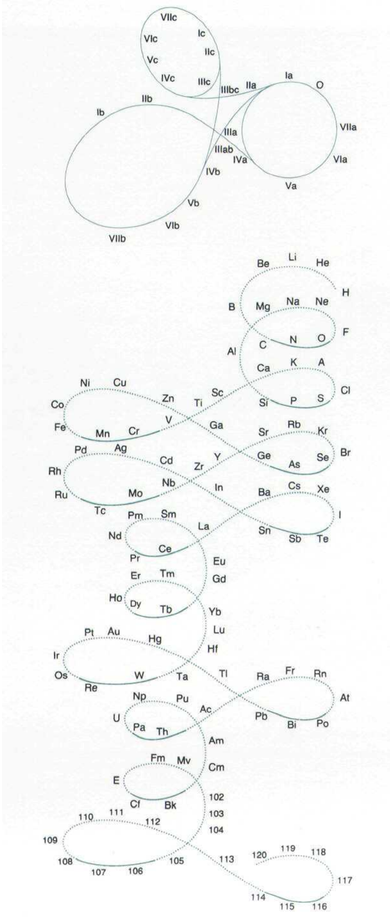
[2] John White, *The Birth and Rebirth of Pictorial Space* (London, 1957); and Lawrence Wright, *Perspective in Perspective* (London, 1983). See also the remarkable book by Kim Veltman, *Linear Perspective and the Visual Dimensions of Science and Art: Studies on Leonardo da Vinci I* (München, 1986).

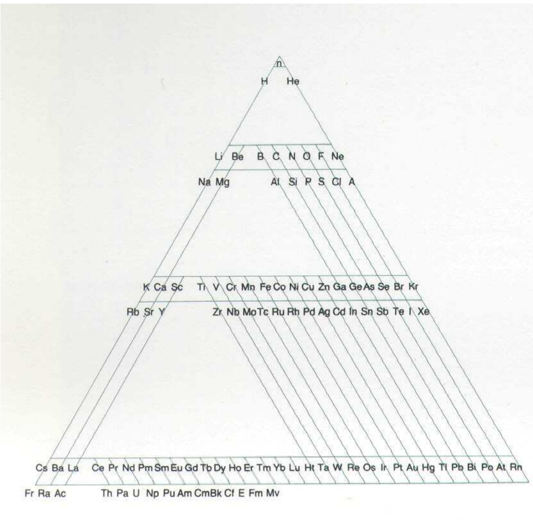
[3] Redrawn from Emil v. Zmaczynski, "Periodic System of the Elements in a New Form," *Journal of Chemical Education, 12* (1935), 265-267; Frank Austin Gooch and Claude Frederic Walker, *Outline of Inorganic Chemistry, //* (London, 1905), pp. 8-9; and Andreas von Antropoff, "Eine neue Form des periodischen Systems der Elemente, "*Zeitschrift für Angewandte Chemie*, 39 (1926), 722-728; Edward Mazurs, *Types of Graphic Representation of the Periodic System of Chemical Elements* (La Grange, Illinois, 1957).

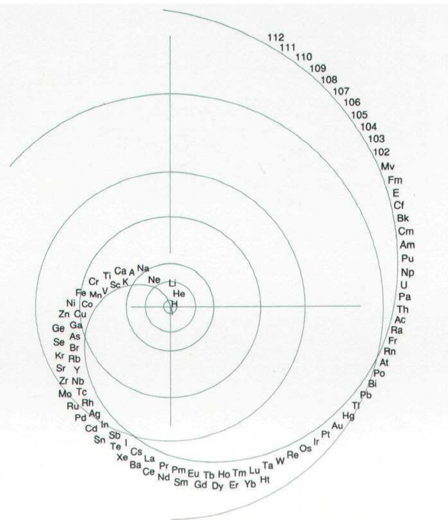
When the toad *(Bufo americanus Le Conte)* sheds its skin upon the occasion of a quarterly moulting, the suit leaves life's spaceland and collapses into flatland, not unlike our information displays.



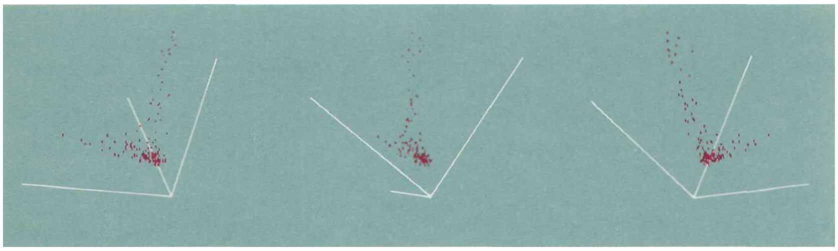
All sorts of techniques for doing better than flattened-out toad suits have evolved during some 500 years of information design.[2] Since the 15th-century Italian Renaissance, when Florentine architects perfected the necessary geometry, conventional perspective drawing has enriched representations of physical objects. And, for more abstract multivariate information not residing in our three-space reality, several enterprising methods have evolved—nearly silently, often to be found in workaday diagrams of those confronted with an overwhelming quantity of data. A few such techniques are well documented; for example, the elaborate structuring of the periodic table of chemical elements[3] (with several







hundred arrangements proposed to capture the assorted complexities). Some recently perfected statistical graphics, self-consciously multivariate, enrich flatland with the dynamics of rotating point clouds on



computer screens — a marvel, although navigation in three-dimensional scatterplots is not a trivial matter.[4] Another approach, here on the right, slices and projects data from many angles onto six of the twelve surfaces of a pentagonal dodecahedron (only six faces are needed, since opposite parallel faces show identical views).

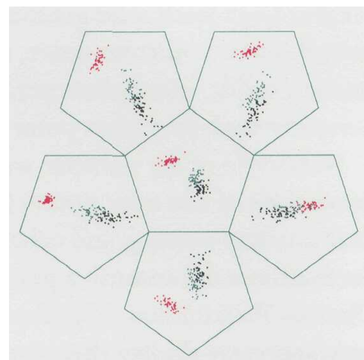
Nearly every escape from flatland demands extensive compromise, trading off one virtue against another; the literature consists of partial, arbitrary, and particularistic solutions; and neither clever idiosyncratic nor conventionally adopted designs solve the inherent general difficulties of dimensional compression. Even our language, like our paper, often lacks immediate capacity to communicate a sense of dimensional complexity. Paul Klee wrote to this point:

> It is not easy to arrive at a conception of a whole which is constructed from parts belonging to different dimensions. And not only nature, but also art, her transformed image, is such a whole.
>
> It is difficult enough, oneself, to survey this whole, whether nature or art, but still more difficult to help another to such a comprehensive view.
>
> This is due to the consecutive nature of the only methods available to us for conveying a clear three-dimensional concept of an image in space, and results from deficiencies of a temporal nature in the spoken word.
>
> For, with such a medium of expression, we lack the means of discussing in its constituent parts, an image which possesses simultaneously a number of dimensions.[5]

And perspective projection is a simple extension of a two-surface, made unmistakable by everyday experience in three-space itself. Yet much of our data — and nature's pattern — have far greater complexity. What, then, are general strategies for extending the dimensional and informational reach of display flatlands? And what specific techniques effectively document and envision multivariate worlds? Why are some performances better than others?

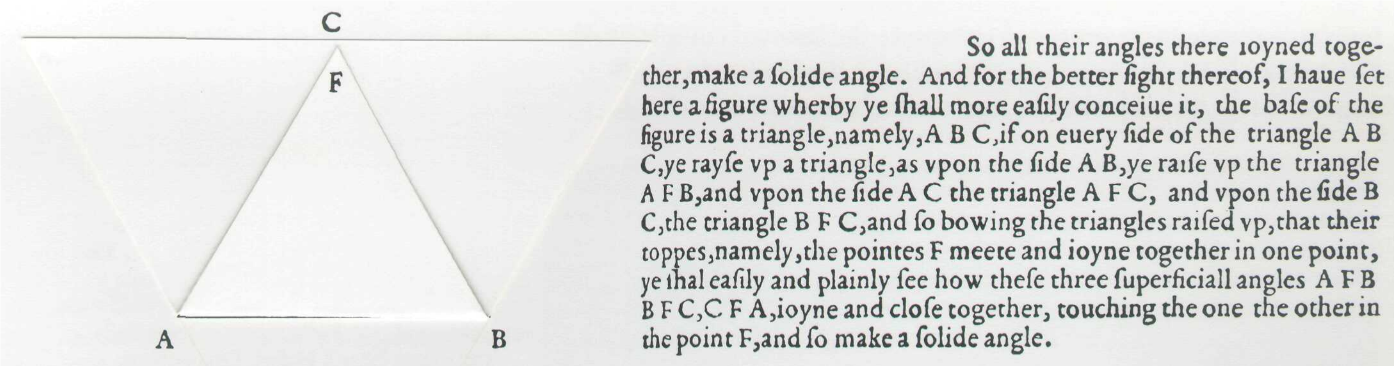
To begin, a series of splendid examples.

[4] Andrew W. Donoho, David L. Donoho, Miriam Gasko, MACSPIN *Graphical Data Analysis Software* (Austin, Texas, 1985), illustration at p. 35 (redrawn); and the important 1974 paper by Mary Anne Fisherkeller, Jerome H. Friedman, and John W. Tukey, "prim-9: An Interactive Multidimensional Data Display and Analysis System," in William S. Cleveland, ed., *The Collected Works of John W. Tukey, Volume V, Graphics: 1965-1985* (Pacific Grove, California, 1988), 308-327. For a report of some difficulties, see Peter J. Huber, "Experiences with Three-Dimensional Scatterplots," *Journal of the American Statistical Association,* 82 (June 1987), 448-453.



Showing the oft-plotted Anderson data for *Iris setosa* •, *Iris versicolor* •, and *Iris virginica* •, redrawn from Paul A. Tukey and John W. Tukey, "Preparation; Prechosen Sequences of Views," in V. Barnett, ed., *Interpreting Multivariate Data* (New York, 1981), pp. 205-206.

[5] Paul Klee, *On Modern Art* (London, 1948), p. 15, translated by Paul Findlay from *Über die moderne Kunst* (Bern, 1945). Recent computer adventures seek to give dimensionality and nonlinearity to text. See E. J. Conklin, "Hypertext: An Introduction and Survey," *Computer* (September 1987), 17-41.



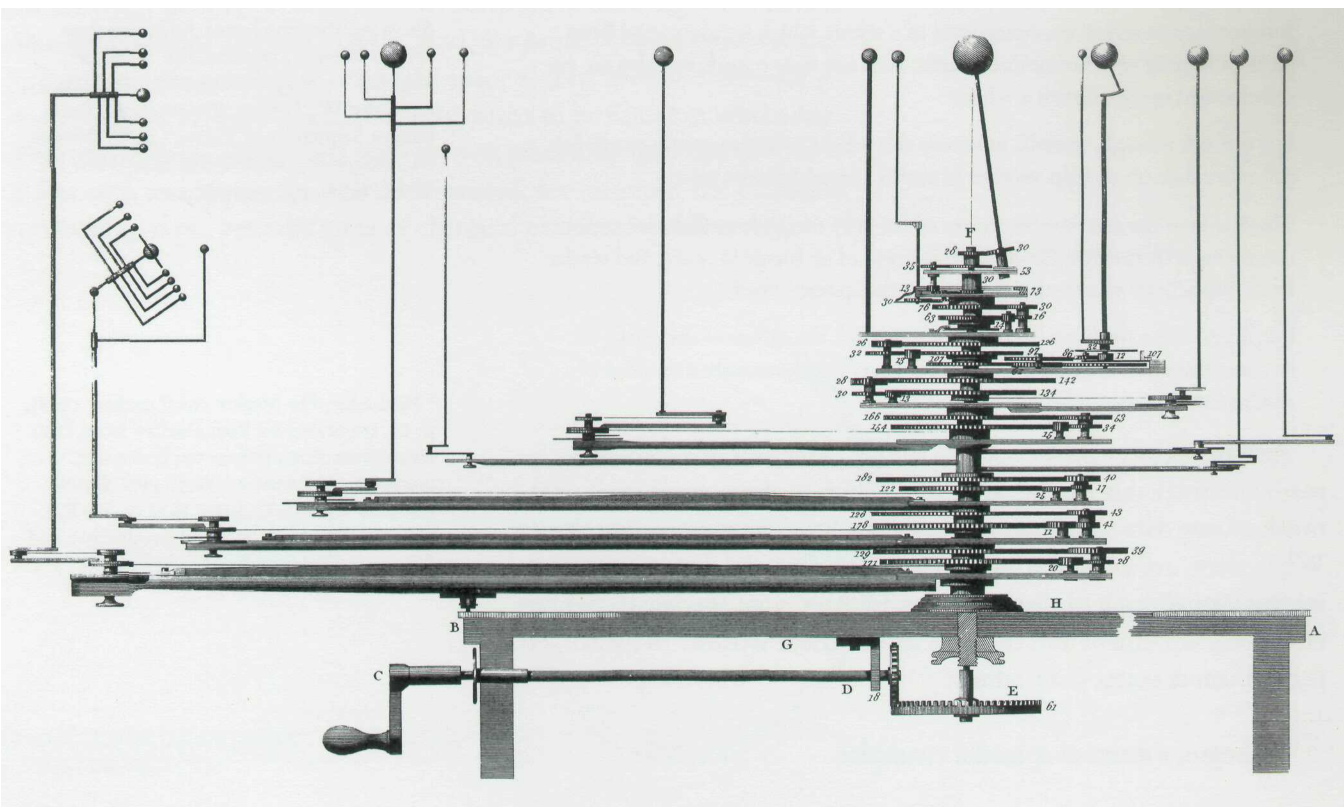
So all their angles there ioyned together, make a ſolide angle. And for the better ſight thereof, I haue ſet here a figure wherby ye ſhall more eaſily conceiue it, the baſe of the figure is a triangle, namely, A B C, if on euery ſide of the triangle A B C, ye rayſe vp a triangle, as vpon the ſide A B, ye raiſe vp the triangle A F B, and vpon the ſide A C the triangle A F C, and vpon the ſide B C, the triangle B F C, and ſo bowing the triangles raiſed vp, that their toppes, namely, the pointes F meete and ioyne together in one point, ye ſhal eaſily and plainly ſee how theſe three ſuperficiall angles A F B B F C, C F A, ioyne and cloſe together, touching the one the other in the point F, and ſo make a ſolide angle.

DIRECT methods for the display of three dimensions include making models, as in this 1570 edition of Euclid's *Elements,* where little paper constructions teach solid geometry. Models pleasingly represent the smooth surfaces of three-space, as in architectural miniatures and mathematical solids; more obstreperous statistical data however, call for computer analysis of data point clouds.

Narratives of the universe were impressively cranked up in orreries, simulations of our solar system (as known in 1800), with planets and their satellites rotating and orbiting. Although a triumph of gear ratios, the machines did commit a grave sin of information design — Pridefully Obvious Presentation — by directing attention more toward miraculous contraptionary display than to planetary motion.

Euclid, *The Elements of Geometrie* (London, 1570), with preface by John Dee, English translation by Henry Billingsley, fol. 314. A fine guide to various extra-dimensional elaborations in book design is Gay Walker, *Eccentric Books* (New Haven: Yale University Library, 1988).

William Pearson, "Planetary Machines," in Abraham Rees, ed., *The Cyclopaedia; or, Universal Dictionary of Arts, Sciences, and Literature, Plates, Vol.* IV (London, 1820), plate XI; and Henry C. King with John R. Millburn, *Geared to the Stars: The Evolution of Planetariums, Orreries, and Astronomical Clocks* (Toronto, 1978).



Color stereopair of Bonaduz, Canton of Grisons, Switzerland, October, 1975, photographs taken with Wild Leitz aerial camera RCIO. Scale about 1:11,000.

[6] Stereoscopic viewers will assist in obtaining three-dimensional images. The effects can be seen without optical devices by some, however. The views here are arranged for the *wide-eyed* or *pie-eyed* method of viewing stereograms; those using the popular *cross-eyed* method will see sunken mountains and raised rivers. See Thomas Avery and Graydon Berlin, *Interpretation of Aerial Photographs* (Minneapolis, 4th edition, 1985), pp. 25-90.

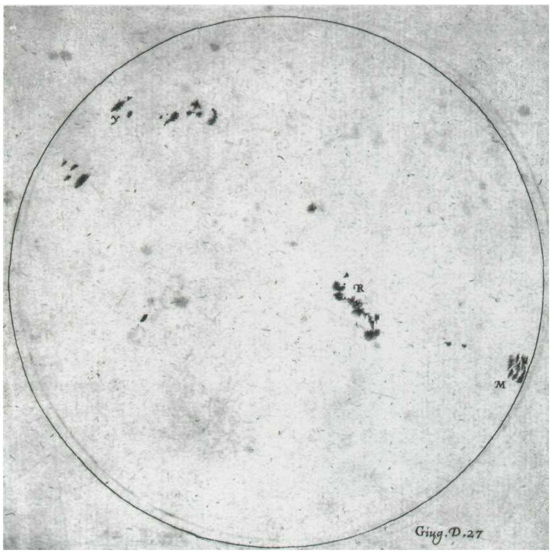
Particularly intriguing are stereo illustrations, which deliver vivid three-dimensional scenes by means of paired images (one for each eye), which are then fused mentally by viewers. Aerial landscapes, molecular structures, and other worldly objects are commonly portrayed; representations of more abstract and ragged quantitative data are rarely seen. Many viewers must struggle (and some fail) to fuse the images; even experienced eyes may require several minutes of vacant staring before obtaining the splendid stereo view.[6] Recent work on computer visualizations, stereo images, holograms, and so on hint at an increasing depth and pace to analytic displays, perhaps eventually without all the paraphernalia accompanying current methods.[7]

[7] Promising results are D. B. Carr, W. L. Nicholson, R. J. Littlefield, and D. L. Hall, "Interactive Color Display Methods for Multivariate Data," and K. R. Gabriel and C. L. Odoroff, "Illustrations of Model Diagnosis by Means of Three-Dimensional Biplots," in Edward J. Wegman and Douglas J. DePriest, *Statistical Image Processing and Graphics* (New York, 1986), 215-250, 258-274; Thomas V. Papathomas, James A. Schiavone, and Bela Julesz, "Stereo Animation for Very Large Data Bases," *Computer Graphics and Applications* (September, 1987), 18-27; and William S. Cleveland and Marylyn E. McGill, eds., *Dynamic Graphics for Statistics* (Belmont, California, 1988).

SUNSPOTS were examined in detail by telescope in the early 1600s, after some 200 years of repeated viewing by unaided eyes in Athens, China, Japan, and Russia. It was difficult for Europeans to see sunspots at all because Aristotle had said that celestial bodies were perfect and without blemish, a fancy which became official church doctrine in the middle ages.[8] Then, in 1610-1612, Galileo and others made detailed telescopic observations of sunspots.

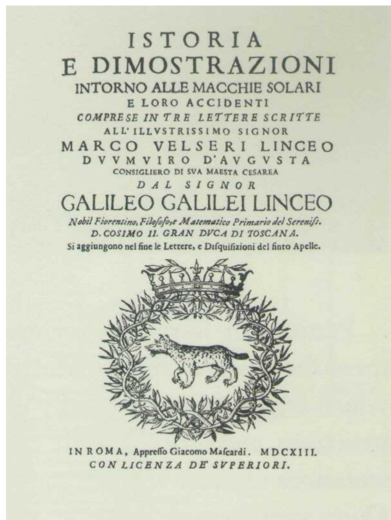
Galileo marked spots directly onto paper flatland, maintaining the proper image plane while drawing a large diagram of a spotted sun:

> The method is this: Direct the telescope upon the sun as if you were going to observe that body. Having focused and steadied it, expose a flat white sheet of paper about a foot from the concave lens; upon this will fall a circular image of the sun's disk, with all spots that are on it arranged with exactly the same symmetry as in the sun. The more the paper is moved away from the tube, the larger this image will become, and the better the spots will be depicted. Thus they will all be seen without damage to the eye, even the smallest of them—which, when observed through the telescope, can scarcely be perceived, and only with fatigue and injury to the eyes.



> In order to picture them accurately, I first describe on the paper a circle of the size that best suits me, and then by moving the paper towards or away from the tube I find the exact place where the image of the sun is enlarged to the measure of the circle I have drawn. This also serves me as a norm and rule for getting the plane of the paper right, so that it will not be tilted to the luminous cone of sunlight that emerges from the telescope. For if the paper is oblique, the section will be oval and not circular, and therefore will not perfectly fit the circumference drawn on the paper. By tilting the paper the proper position is easily found, and then with a pen one may mark out spots in their right sizes, shapes, and positions. But one must work dextrously, following the movement of the sun and frequently moving the telescope, which must be kept directly on the sun.[9]

[8] George Sarton, "Early Observations of the Sunspots," *Isis*, 37 (May 1947), 69-71; for the full history, D. Justin Schove, ed., *Sunspot Cycles* (Stroudsburg, Pennsylvania, 1983).



ISTORIA
E DIMOSTRAZIONI
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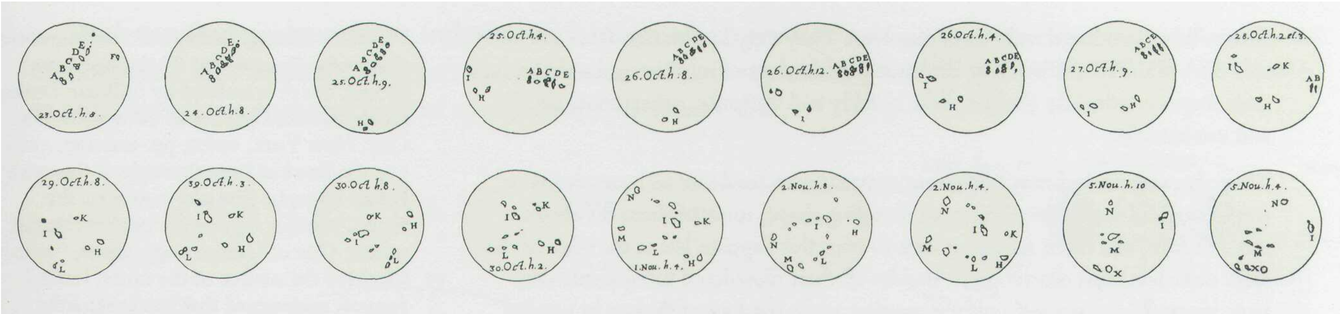
DVVMVIRO D'AVGVSTA
CONSIGLIERO DI SVA MAESTA CESAREA
DAL SIGNOR
GALILEO GALILEI LINCEO
Nobil Fiorentino, Filosofo, e Matematico Primario del Sereniss.
D. COSIMO II. GRAN DVCA DI TOSCANA.
Si aggiungono nel fine le Lettere, e Disquisizioni del finto Apelle.

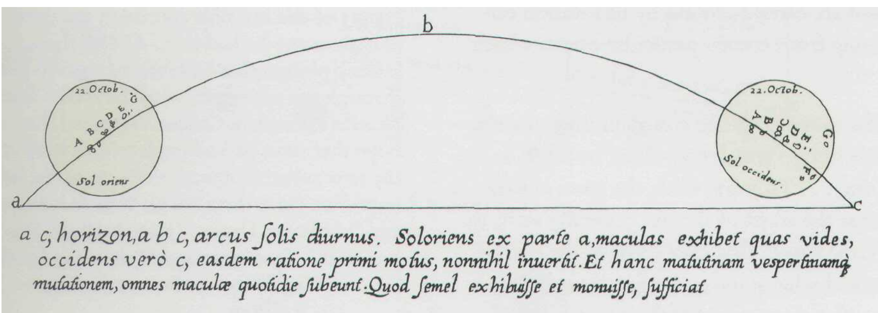
IN ROMA, Appresso Giacomo Mascardi. MDCXIII.
CON LICENZA DE' SVPERIORI.

[9] Galileo Galilei, *History and Demonstrations Concerning Sunspots and Their Phenomena* (Rome, 1613), translated by Stillman Drake, *Discoveries and Opinions of Galileo* (Garden City, New York, 1957), pp. 115-116.



As more observations were collected daily, small multiple diagrams recorded the data indexed on time (a design simultaneously enhancing dimensionality and information density0, with the labeled sunspots parading along alphabetically. This profoundly multivariate analysis — showing sunspot location in two-space, time, labels, and shifting relative orientation of the sun in our sky — reflects data complexities that arise because a rotating sun is observed from a rotating and orbiting earth:

Illustrations from Christopher Scheiner (writing under the pseudonym "Apelles"), *De Maculis Solaribus* (Rome, 1613), pp. 14-15; and his *Rosa Ursina sive Sol* (Bracciani, 1626-1630), p. 63. On the dispute between Galileo and Scheiner concerning sunspots, see William Shea, *Galileo's Intellectual Revolution* (New York, 1972), pp. 48-74.



For some astronomers, particularly those seeking to reconcile data with doctrine, it was unclear just where sunspots were located. Surely not on the surface of that perfect sphere; perhaps satellites orbited the sun, or even planets were in transit across the sun's face — speculations soon demolished by Galileo. Through an elegant chain of visual reasoning and with characteristic sardonic bluntness, Galileo, writing from Florence in August 1612, converts empirical observation into focused evidence supporting conclusions. His argument unfolds the raw data ("what the eye of the forehead" registers) into a luminous explanation of mechanism ("what the eye of the mind" envisions),[10] a deeply visual logic that produced precise insights far beyond those achieved by others who had also observed sunspots in the early 1600s. Indeed, "it was more than 150 years before any important addition was made"[11] to Galileo's results, as reported in 1613:

> I therefore repeat and more positively confirm to Your Excellency that the dark spots seen in the solar disk by means of the telescope are not at all distant from its surface, but are either contiguous to it or separated by an interval so small as to be quite imperceptible. Nor are they stars or other permanent bodies, but some are

[10] The persistent relationship between artistic capacity for visualization and extraordinary scientific achievement is described in Robert Scott Root-Bernstein, "Visual Thinking: The Art of Imagining Reality," *Transactions of the American Philosophical Society*, 75 (1985), 50-67. For further evidence about Galileo, see Erwin Panofsky, *Galileo as a Critic of the Arts* (The Hague, 1954), p. 5: An excellent draughtsman, Galileo loved and understood 'with perfect taste' all the 'arts subordinated to design' . . . he was originally inclined to study painting rather than mathematics, and one of his most intimate and faithful friends was the outstanding painter of their native Florence, Ludovico Cigoli."

[11] R. J. Bray and R. E. Loughhead, *Sunspots* (London, 1964), p. 2. Galileo's analysis attained special longevity because of its insight and also the nearly complete absence of observable sunspots from 1645 until 1715! John A. Eddy, "The Maunder Minimum," *Science, 192* (June 18, 1976), 1189-1202.

always being produced and others dissolved. They vary in duration from one or two days to thirty or forty. For the most part they are of most irregular shape, and their shapes continually change, some quickly and violently, others more slowly and moderately.

They also vary in darkness, appearing sometimes to condense and sometimes to spread out and rarefy. In addition to changing shape, some of them divide into three or four, and often several unite into one; this happens less at the edge of the sun's disk than in its central parts. Besides all these disordered movements they have in common a general uniform motion across the face of the sun in parallel lines. From special characteristics of this motion one may learn that the sun is absolutely spherical, that it rotates from west to east around its own center, carries the spots along with it in parallel circles, and completes an entire revolution in about one lunar month. Also worth noting is the fact that the spots always fall in one zone of the solar body, lying between the two circles which bound the declinations of the planets - that is, they fall within 28° or 29° of the sun's equator.

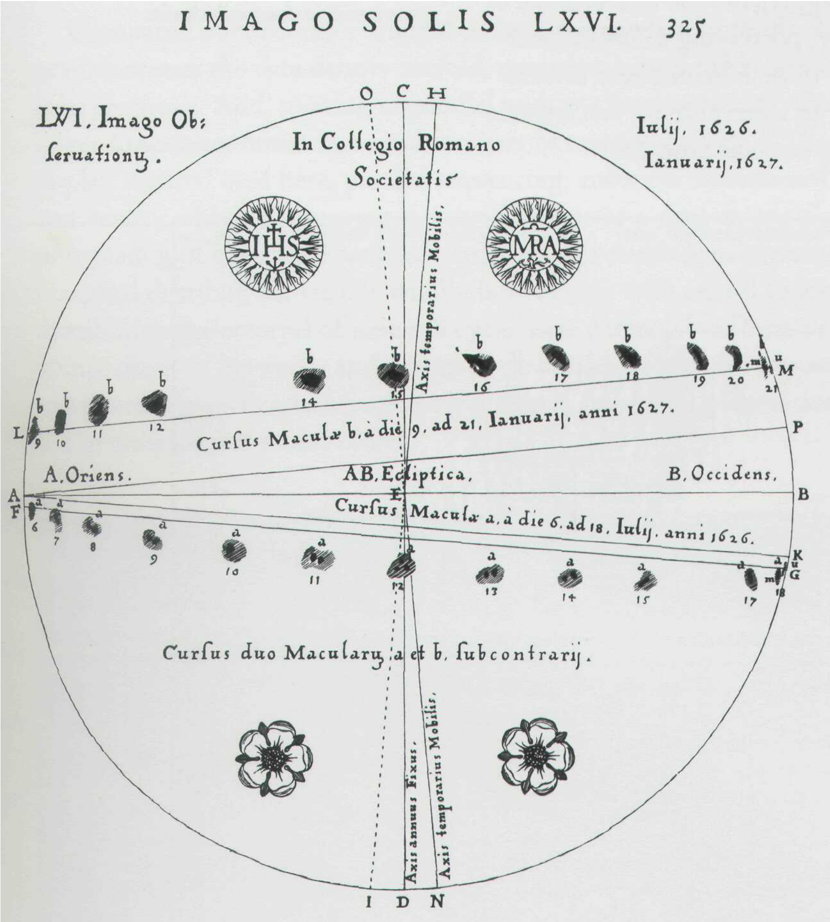
The different densities and degrees of darkness of the spots, their changes of shape, and their collecting and separating are evident directly to our sight, without any need of reasoning, as a glance at the diagrams which I am enclosing will show. But that the spots are contiguous to the sun and are carried around by its rotation can only be deduced and concluded by reasoning from certain particular events which our observations yield.

First, to see twenty or thirty spots at a time move with one common movement is a strong reason for believing that each does not go wandering about by itself, in the manner of the planets going around the sun. . . . To begin with, the spots at their first appearance and final disappearance near the edges of the sun generally seem to have very little breadth, but to have the same length that they show in the central parts of the sun's disk. Those who understand what is meant by foreshortening on a spherical surface will see this to be a manifest argument that the sun is a globe, that the spots are close to its surface, and that as they are carried on that surface toward the center they will always grow in breadth while preserving the same length. . . . this maximum thinning, it is clear, takes place at the point of greatest foreshortening....

I have since been much impressed by the courtesy of nature, which thousands of years ago arranged a means by which we might come to notice these spots, and through them to discover things of greater consequence. For without any instruments, from any little hole through which sunlight passes, there emerges an image of the sun with its spots, and at a distance this becomes stamped upon any surface opposite the hole. It is true that these spots are not nearly as sharp as those seen through the telescope, but the majority of them may nevertheless be seen. If in church some day Your Excellency sees the light of the sun falling upon the pavement at a distance from some broken window pane, you may catch this light upon a flat white sheet of paper, and there you will perceive the spots. I might add that nature has been so kind that for our instruction she has sometimes marked the sun with a spot so large and dark as to be seen merely by the naked eye, though the false and inveterate idea that the heavenly bodies are devoid of all mutation or alteration has made people believe that such a spot was the planet Mercury coming between us and the sun, to the disgrace of past astronomers.[12]

[12] Galileo Galilei, *History and Demonstrations Concerning Sunspots and Their Phenomena* (Rome, 1613), translated by Stillman Drake, *Discoveries and Opinions of Galileo* (Garden City, New York, 1957), pp. 106-107, 116-117. Galileo had been through all this once before when he first saw craters on the moon, another supposedly perfect celestial sphere. One of Galileo's opponents, "who admitted the surface of the moon looked rugged, maintained that it was actually quite smooth and spherical as Aristotle had said, reconciling the two ideas by saying that the moon was covered with a smooth transparent material through which mountains and craters inside it could be discerned. Galileo, sarcastically applauding the ingenuity of this contribution, offered to accept it gladly — provided that his opponent would do him the equal courtesy of allowing him then to assert that the moon was even more rugged than he had thought before, its surface being covered with mountains and craters of this invisible substance ten times as high as any he had seen. At Pisa the leading philosopher had refused even to look through the telescope; when he died a few months afterward, Galileo expressed the hope that since he had neglected to look at the new celestial objects while on earth, he would now see them on his way to heaven." Stillman Drake, "Introduction: Second Part," *Discoveries and Opinions of Galileo* (Garden City, New York, 1957), p. 73.

With continuing observation, indexing each image afresh grew cumbersome. Christopher Schemer's *Rosa Ursina sive Sol*, completed in 1630, arrays the apparent path of spots across a stationary disk,

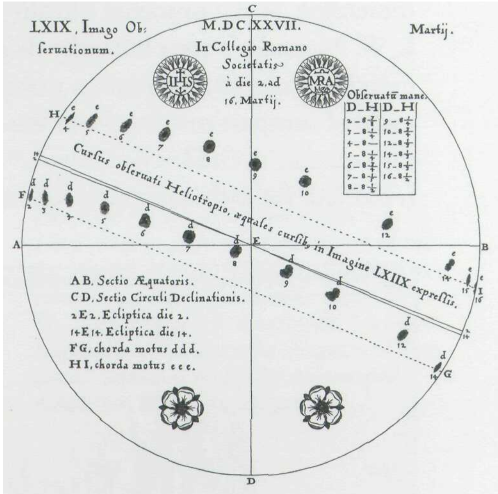


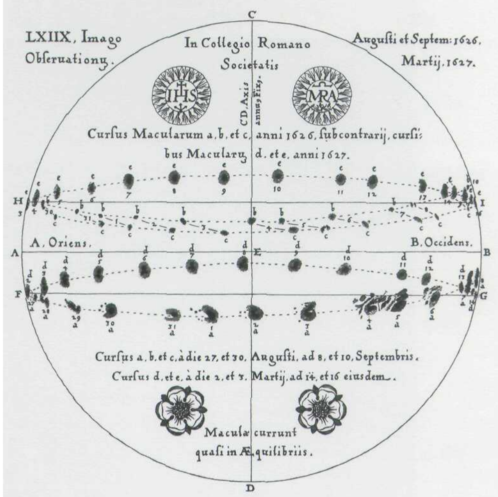
an ingenious method for tracking simple sunspot structures but tending to jumble up complex data. Symbols of Scheiner's patron and religious order decorate those areas without spots in a hundred such diagrams, a reminder of Jonathan Swift's indictment of 17th-century cartographers who substituted embellishment for data:

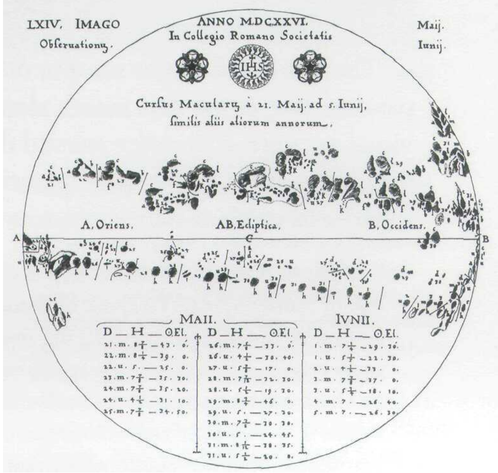
With savage pictures fill their gaps,
And o'er unhabitable downs,
Place elephants for want of towns

These symbols, similar to a modern trademark or logotype, may have served as a seal of validation for the readers of 1630. Today they appear somewhat strident, contradicting nature's rich pattern.

Christopher Scheiner, *Rosa Ursina sive Sol* (Bracciani, 1626-1630), pp. 317, 325, 333, and 339.

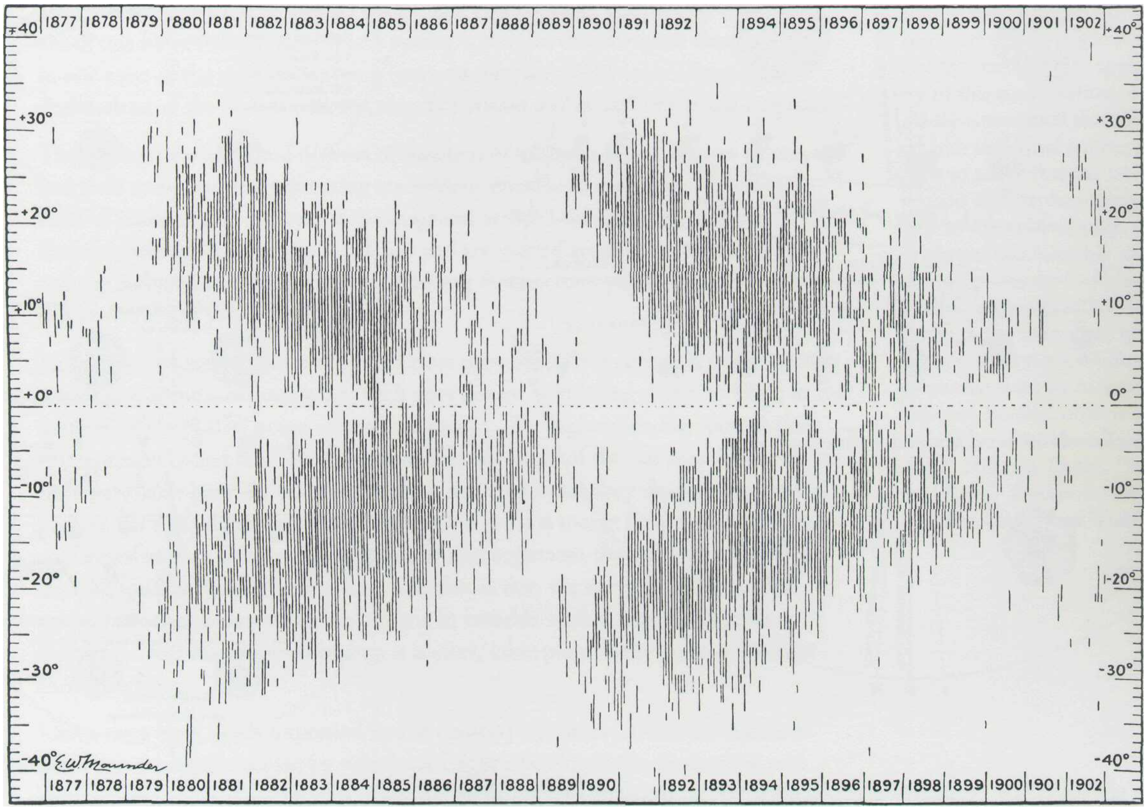






Years and years of daily mapping led to this superb visualization, sunspot distribution in latitude, recorded for long time periods. The sunspot's two areal dimensions are reduced to one content-relevant dimension, as the immense quantity of data provoked design mastery. E.W. Maunder's 1904 butterfly diagram aggregates the micro-detail of individual observations into a macro-view, portraying a *distributional* cycle of sunspots moving from the center of each hemisphere toward the equator, as Galileo had noted.[13] Only an interval + 40° sun latitude is plotted, for little activity is seen in more extreme latitudes:

[13] E. W. Maunder, "Notes on the Distribution of Sun-spots in Heliographic Latitude, 1874 to 1902," *Royal Astronomical Society Monthly Notices, 64* (1904), 747-761. The data compression here consists of taking only the *vertical* dimension of the sunspot, measured in degrees latitude.



The fine detail of this sunspot diagram merges into a repeated typical pattern; and, as the data march along over time, the foremost result is a visual measure *of variation* around that average. Measured assessments of variability are at the heart of quantitative reasoning. R. A. Fisher, the founder of modern statistics, wrote in 1925:

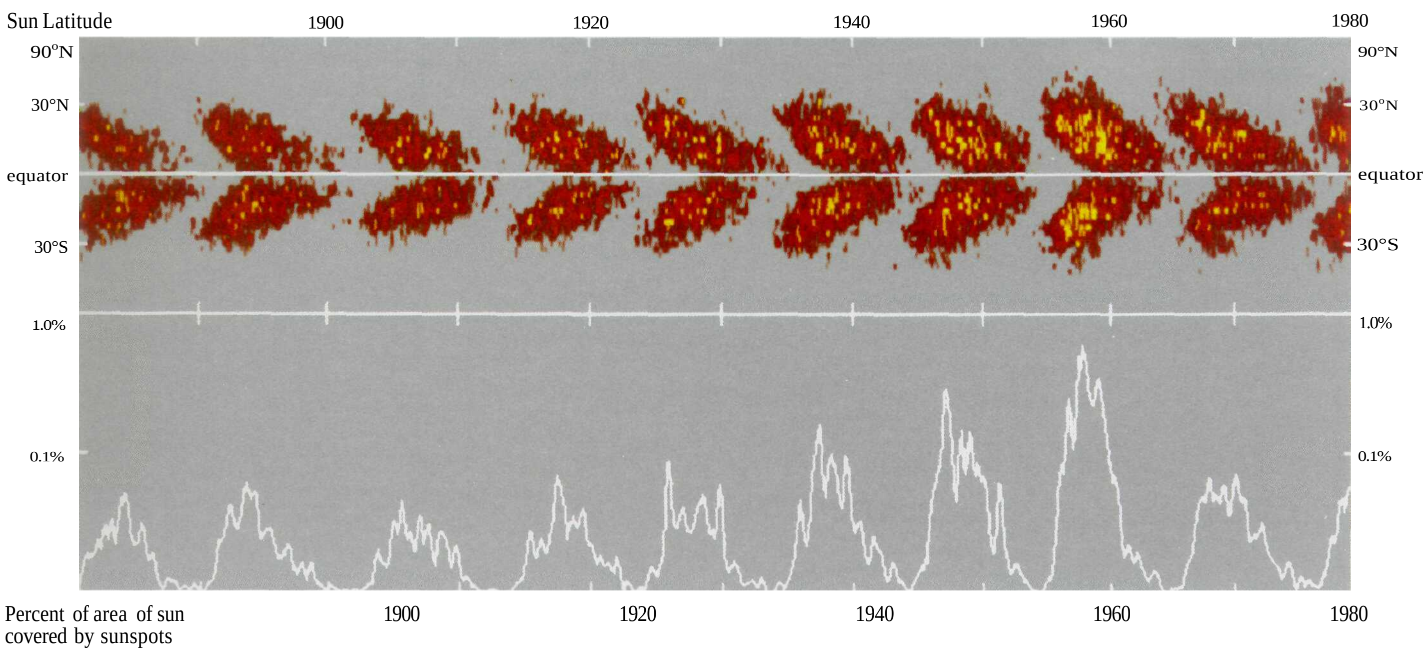
> The populations which are the object of statistical study always display variation in one or more respects. To speak of statistics as the study of variation also serves to emphasize the contrast between the aims of modern statisticians and those of their predecessors. For until comparatively recent times, the vast majority of workers in this field appear to have had no other aim than to ascertain aggregate, or average, values. The variation itself was not an object of study, but was recognized rather as a troublesome circumstance which detracted from the value of the average. The

> error curve of the *mean* of a normal sample has been familiar for a century, but that of the *standard deviation* was the object of researches up to 1915. Yet, from the modern point of view, the study of the causes of variation of any variable phenomenon, from the yield of wheat to the intellect of [people], should be begun by the examination and measurement of the variation which presents itself.[14]

Compared to Maunder's original picture, the modern butterfly diagram increases the data density tenfold, reporting now a full century of solar memoirs. And, moving in parallel with the flapping wings, the lower time-series restores an areal measure of sunspot activity.[15] The display method used here, parallel sequencing, enhances dimensionality and density, although showing the variables one-at-a-time-in-parallel is unrevealing of complex *interrelated* structure. (As statisticians explain, marginal distributions are not wholly informative with regard to joint distributions.) Portrayal of nine full cycles here enforces comfortable comparisons of between- and within-cycle variation, and also exposes an apparent growth trend (perhaps it is merely improved observation) in the wingspan of recent cycles.

[14] Ronald A. Fisher, *Statistical Methods for Research Workers* (Edinburgh, 1925; 13th edition, 1958), p. 3.

[15] Since the sunspots appear symmetric about the sun's equator, the wings may be folded over to show the distribution of the sun latitude of spots without distinction between northerly and southerly sunspots. W. Gleissberg and T. Damboldt, "A New Approach to the Butterfly Diagram of Sunspots," *Journal of the British Astronomical Association*, 81 (1971), 271-276.



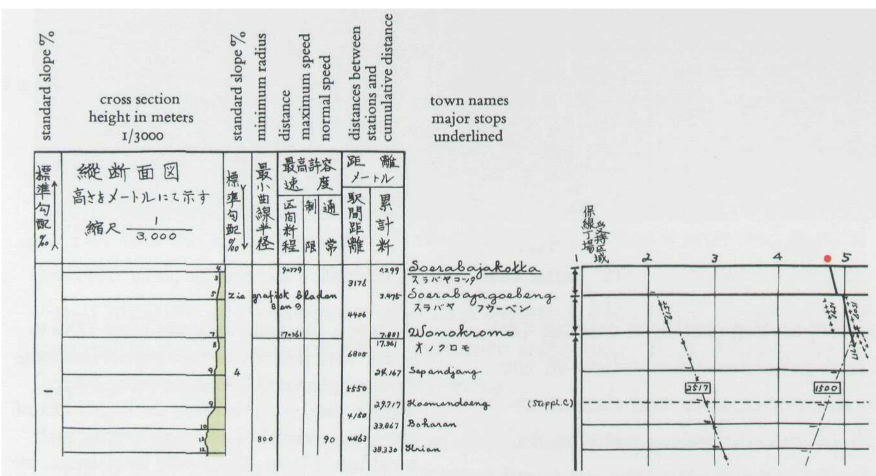
At top, a Maunder diagram from 1880 to 1980, with the sine of the latitude marking sunspot placement. Color coding (the lighter, the larger) reflects the logarithm of the area covered by sunspots within each areal bin of data. The lower time-series, by summing over all latitudes, shows the total area of the sun's surface covered by sunspots at any given time during the hundred-year sequence. Diagrams produced by David H. Hathaway, George C. Marshall Space Flight Center, National Aeronautics and Space Administration.

Note all the different techniques for displaying sunspots during 380 years of data analysis—from Galileo's first precious observation of the solar disk, to small multiple images, to dimensionality and data compression, and finally to micro/macro displays combining pattern and detail, average and variation. *Exactly the same design strategies are found, again and again, in the work of those faced with a flood of data and images, as they scramble to reveal, within the cramped limits of flatland, their detailed and complex information. These design strategies are surprisingly widespread, albeit little appreciated, and occur quite independently of the content of the data.*

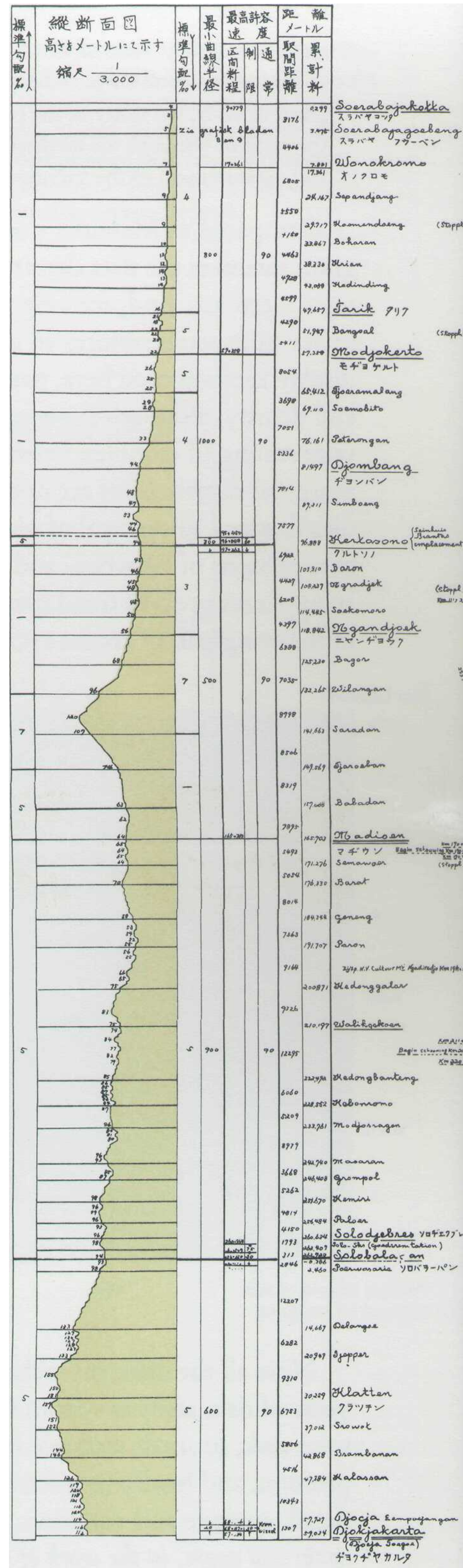
WONDROUSLY complex is this graphic timetable for a Java railroad line, Soerabaja-Djokjakarta, drawn in November 1937 (annotated in Dutch, then in Japanese). By smoothly suppressing a dimension first here and then several times there, finessing perspective treatments entirely, and changing the focus, this 24-hour railroad plan abstractly traces out multiple paths through three-space and time, in a four-dimensional tour with a dozen other variables carried along.

The time scale is read across the top; towns on the railroad route are indicated by names stacked down the column at left. Diagonal lines running from upper left to lower right show trains heading down \\ , return trains by diagonals going from lower left to upper right //. The first train from the top station, Soerabajakotta, leaves at about 4:50 in the morning (at the • dot), and then reaches the first stop just a few minutes later, and so on. Steeper lines are the faster trains. When trains going opposite directions pass by, an X appears. The arrangement repays meticulous study:

- Graphical timetables turn the three spatial dimensions of our daily world into one train-relevant dimension by measuring distance along the track itself. Horizontal grid lines, marking towns and station stops, are spaced approximately in proportion to their distance apart along the rails (yielding straight-line diagonals, assuming trains run more or less at constant speed over the entire route).
- The left margin of the timetable reflects another viewpoint, with a profile (at an enlarged vertical scale) of all the valleys and mountains crossed by rail. This visual depiction is accompanied by quantitative details, to the right of the profile, where columns of numbers describe the grade and path. Note how the vertical has been used repeatedly to



array parallel sequences of thoroughgoing data. In flatland, after all, every opportunity to spread additional information over an already-available dimension must be cherished.



1937年11月16日現在

Soerabaja-Djokjakarta.

スラバヤ　チヨクヂヤカルタ

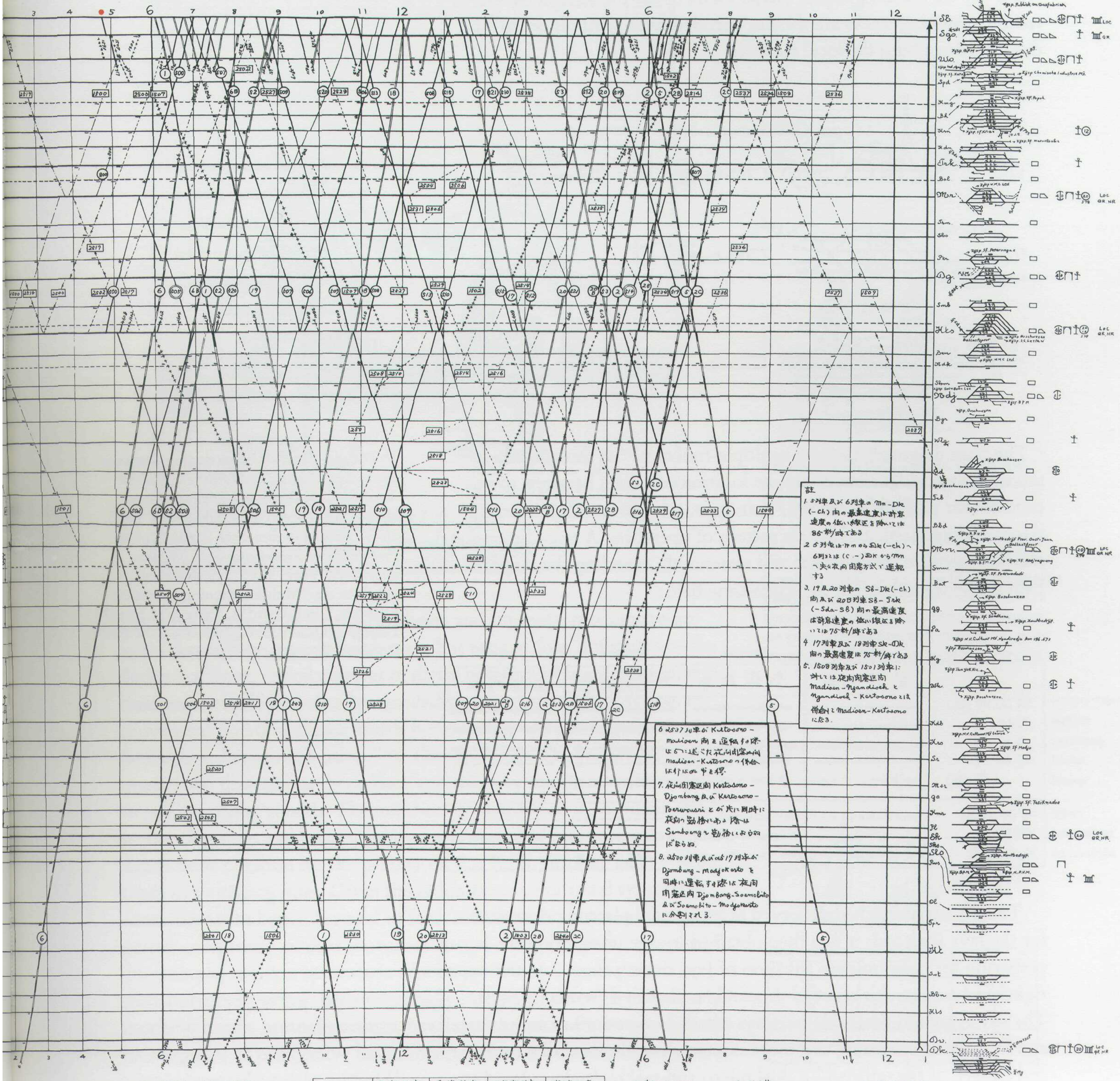
（時刻はジヤワ時間にて示す）

列車休泊区間

- Sb v/h lijnwak Sb - Mn
- Kts " " Mn - Kts
- Mn " { Kts - Mn / Mn - Wk
- Sb v/h lijnwak { Wk - Sb / Sk - Sko - Slo / Slo - Dk (alleen voor SS treinen)
- Dk voor de SS treinen uitsluitend rijdende tusschen Wk en Dv

祕

第７表



註

1. 5列車及び6列車のMn-Dk(-Ch)間の最高速度は許容速度の低い線区を除いては85粁/時である
2. 5列車はMnからDk(-Ch)へ 6列車は(C-)DkからMnへ夫々夜間閉塞方式で運転する
3. 19及20列車のSb-Dk(-Ch)間及び20B列車Sb-Jnk(-Sda-Sb)間の最高速度は許容速度の低い線区を除いては75粁/時である
4. 17列車及び18列車Sk-Dk間の最高速度は75粁/時である
5. 1508列車及び1501列車に対しては夜間閉塞区間Madioen-Ngandioek とNgandioek-Kertosonoとは併合してMadioen-Kertosonoになる.
6. 2537列車がKertosono-Madioen間を運転する際は5に述べた夜間閉塞区間Madioen-Kertosonoの併合は行はぬ事を得
7. 夜間閉塞区間Kertosono-Djombang及びKertosono-Poerwoasriとが共に同時に夜間の勤務にある際はSemboengで勤務しなければならぬ.
8. 2500列車及び2517列車がDjombang-Madjokertoを同時に運転する際は夜間閉塞区間Djombang-Soemobito及びSoemobito-Madjokertoに分割される.

太いアンダラインの駅は機関区(又は支区)の所在駅
細いアンダラインの駅は規程19第一章にかいる交換駅
F＝特定の日のみの出来るだけ短時間の停車
ヤ＝出来るだけ短時間の停車
—＝通過
ZO＝日曜日に
DO＝祭日に
◎＝一定の条件の下で貨物をも運んでよい最高速度50粁/時の旅客列車

	定期列車	季節列車	不定期列車	臨時列車
特急列車				
急行 "				
旅客 "				
混合 "				
混合(特殊)				
貨物列車				
職用 "				
夜間貨物 "				

□ 前部プラットホーム
▷ "
△ 家畜積込用プラットホーム
▽ 信号機械
⌶ トラバーサ
♀ 給水柱
○ 転車台
Ⅲ 監理プラットホーム
LoC＝予備機関車
GR.Nh.＝組架車及救援車

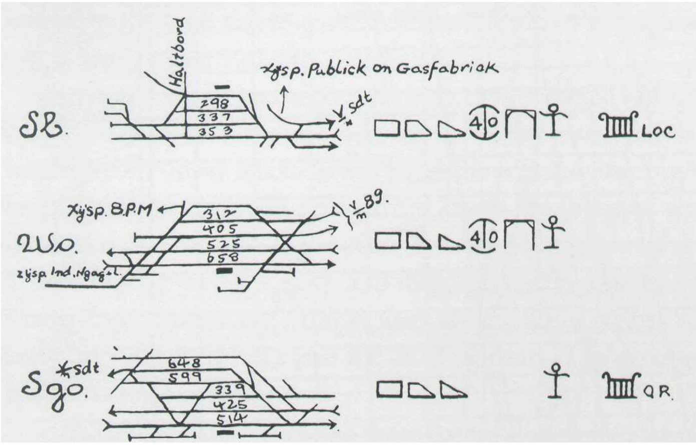
矢の方向は上りの方向を示す
A 閉塞法による区間
B "

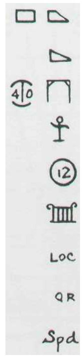
A＝駅長所在駅
B＝駅長不在駅
C＝駅員不在駅

複線区間
Sb-Tnk

閉塞区間 { Bm-Kts-Smb / Spd-Wo-Sgo-Sb

• Within each station, still another view—for what is important here is activity on the flat ground. Aerial views of the intricate networks of station switching tracks are shown, encoded with symbols, icons, and dingbats describing the local facilities:



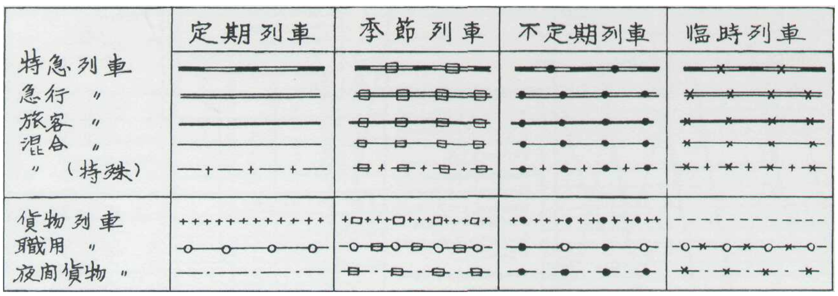


cargo unloading platform
livestock loading platform
cargo unloading facilities
water supply pump tower
directional change platform
car repair platform
standby engines
relief car
closed areas

• The train diagonals cleverly multiple-function,[16] as those marks record six variables all at once: the location of a train between towns, time of that position, direction, train type, relative speed (comparing slopes of diagonals), and yearly pattern of operation. A two-dimensional matrix organizes lines by type and seasonality, encoding the diagonal path of the train through the space-time field:

regular | seasonal | irregular | special

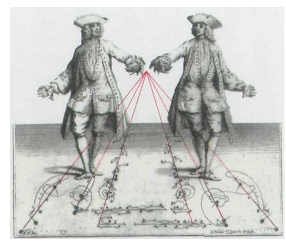
super express
express
passenger
mixed
special
cargo
preferential
night cargo



This 16-variable schedule served as an internal planning document for the Java Railroad; it was then obtained by agents working for Japan preparing for their military invasion of Java during *1942.*[17] In the upper right-hand corner, this railroad timetable is classified "secret" (秘). The spy graphical timetable portrays detailed operations of an intricate and irregular system and, at a more distant view, the overall structure and pattern of the railroad—a dual micro and macro reading. It is very much like an excellent map, but with many dimensions breaking free of direct analogy to conventional cartographic flatland.

[16] The idea of double-functioning elements appears in architectural criticism; Robert Venturi, *Complexity and Contradiction in Architecture* (New York, 2nd edition, 1977), ch. 5. Venturi in turn cites Wylie Sypher, *Four Stages of Renaissance Style* (Garden City, New York, 1955). For statistical graphics, see "Multifunctioning Graphical Elements," in Edward R. Tufte, *The Visual Display of Quantitative Information* (Cheshire, Connecticut, 1983), pp. 139-159.

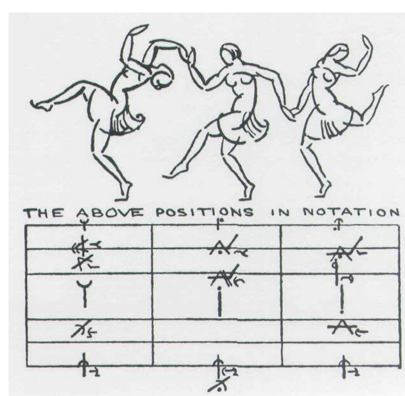
[17] *Indonesia ni okeru nihon gunsei no genkyu [A Study of Japanese Occupation in Indonesia],* Okuma Social Science Center at Waseda University (Tokyo, 1959).



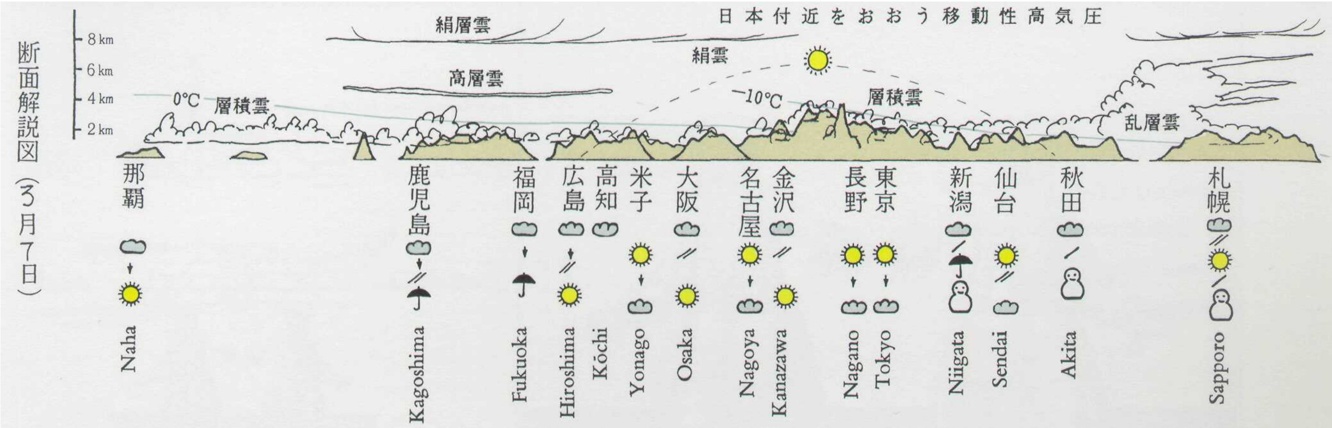
Kellom Tomlinson, *The Art of Dancing, Explained by Reading and Figures* (London, 1735), book I, plate XII.

LIKE the tour-guides for the Ise Shrine and sunspots, movements are again depicted on a perspective map, but now in four dimensions - the flatland of floor, coded gestures in dance notation of body motion, and time sequence. (Symbolically encoded because "any serious system of movement notation avoids words because they are a strong deterrent to international communication."[18]). The floor plan is linked to the airy music (two dimensions there, time and tone) by numbers, with varying steps for varying sounds. The numbers double-function, simultaneously sequencing steps and relating movement to music. Note the enlarged dance-floor notation for the partner on our right, since he takes a front route in switching sides. Often the redundancy of bilateral symmetry consumes space better devoted to fresh information; but here the integrated complexity of dual movements, as the dancers' paths weave and intermingle, requires symmetric repetition. The two, pulled apart by their mirrored pairing, become visually integrated through their nearly touching hands, mutual postures, overlapping paths of movement, and convergence of perspective lines radiating from the flatland floor to a vanishing point exactly midway between their outstretched hands. A subtle, graceful, profoundly simple design, with a straightforward complexity, a forerunner of modern dance and movement notation.

[18] Ann Hutchinson Guest, *Dance Notation: The Process of Recording Movement on Paper* (London, 1984), p. 14. This book also makes a surprising demonstration that abstract, symbolic methods of movement notation are preferable to film and stick figure portrayals, at least from a dancer's viewpoint.



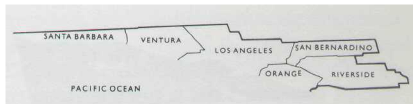
Margaret Morris, *The Notation of Movement* (London, 1928), pp. 103-104.



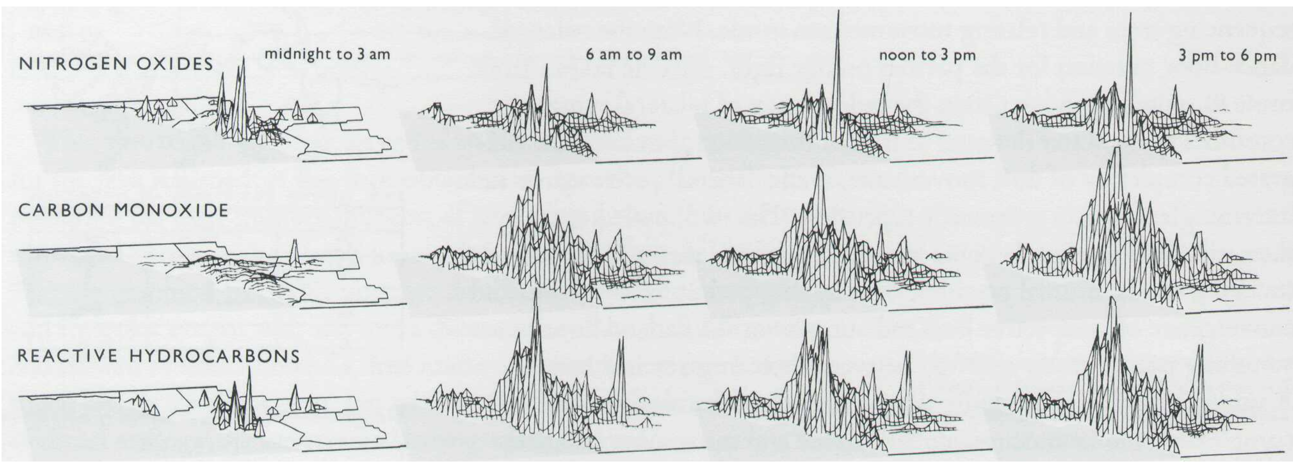
HERE gray contours tracing out constant temperatures at 0° and -10° c stretch through the clouds in a side profile of Japan, an ocean-eye view. Forecasts for 15 areas annotate the cross-section of this unusual weather map from a daily newspaper. How easily the design reads, compared to traditional weather maps that commit both their visual dimensions to a planview of latitude and longitude, suppressing the vertical. Of course the arrangement works best for long, thin countries.

Redrawn from *Akahata* [Red Flag], Tokyo, March 7, 1985. English translation added here. Note the changing weather reported for some cities, for example, Sapporo at the far right of the map.

The next graphic, plotted by a computer, reports four times daily the levels of three air pollutants fuming over southern California. Nitrogen oxides (top row) are emitted by power plants, refineries, and vehicles. Refineries along the coast produce post-midnight peaks shown in the first panel; cars and power plants send daytime levels up. The morning traffic generates carbon monoxide, with high concentrations where five freeways converge in downtown Los Angeles. Reactive hydrocarbons (bottom row) emanate from refineries after midnight and then increase



Redrawn. See G. J. McRae, W. R. Goodin, and J. H. Seinfeld, "Development of a Second-Generation Mathematical Model for Urban Air Pollution. I. Model Formulation," *Atmospheric Environment, 16* (1982), 679-696.



with daily traffic. The twelve time-space-pollutant maps add up smog observations on a spatial grid of 2,400 squares (each five kilometers on a side), for a total of 28,800 readings, except for those masked by peaks—a high density arrangement of data, abounding with variables and with observations on those variables.

This air pollution display is a *small multiple*, with the same design structure repeated for all the images. An economy of perception results; once viewers decode and comprehend the design for one slice of data, they have familiar access to data in all the other slices. As our eye moves from one image to the next, this constancy of design allows viewers to focus on changes in information rather than changes in graphical composition. A steady canvas makes for a clearer picture. Note how paper's two dimensions are put to work here, twice over. Each small map reports on the two-space location of a third quantity; those maps become entries themselves in another matrix arraying time of day by type of pollution, for a grand total of five variables.

Tabular arrays of numbers similarly confront flatland, with design solutions identical to graphical displays. These compound interest tables record a third variable located on the two-surface, and then repeat each array, small multiple style, at levels of a fourth variable. Entries show capital plus interest, entabled for sequenced amounts of capital and time. That grid is then repeated, indexed on the annual rate of interest.

Data entries located on a plane surface can themselves multiply, as in the notorious applicant/admit tables for law school admissions. Knitting together all combinations of college grades and test scores, the bivariate grid registers both the number of applicants and, from those candidates, the number then actually admitted by this law school. The margins on the right and bottom sum up to univariate distributions, with grand totals shown at lower right. This table could in turn become an entry in another two-space, a multiple comparison over time of various schools. And when that array itself becomes another entry . . .

INTÉRÊTS COMPOSÉS A TROIS POUR CENT.

CAPITAL.	1.re ANNÉE.	2.e ANNÉE.	3.e ANNÉE.
f.	f. e.	f. e.	f. e.
1	1 03	1 06	1 09
2	2 06	2 12	2 18
3	3 09	3 18	3 27
4	4 12	4 24	4 37
5	5 15	5 30	5 46
6	6 18	6 36	6 55
7	7 21	7 42	7 64
8	8 24	8 48	8 74
9	9 27	9 54	9 83
10	10 30	10 60	10 92
20	20 60	21 20	21 85
30	30 90	31 80	32 78
40	41 20	42 40	43 70
50	51 50	53 04	54 63
60	61 80	63 65	65 56
70	72 10	74 26	76 49
80	82 40	84 87	87 41
90	92 70	95 48	98 34
100	103 00	106 09	109 27
200	206 00	212 18	218 54
300	309 00	318 27	327 81
400	412 00	424 36	437 09
500	515 00	530 45	546 36
600	618 00	636 54	655 63
700	721 00	742 63	764 90
800	824 00	848 72	874 18
900	927 00	954 81	983 45
1,000	1,030 00	1,060 90	1,092 72
2,000	2,060 00	2,121 80	2,185 45
3,000	3,090 00	3,182 70	3,278 18

INTÉRÊTS COMPOSÉS A QUATRE POUR CENT.

CAPITAL.	1.re ANNÉE	2.e ANNÉE.	3.e ANNÉE.
f.	f. e.	f. e.	f. e.
1	1 04	1 08	1 12
2	2 08	2 16	2 24
3	3 12	3 24	3 37
4	4 16	4 32	4 49
5	5 20	5 40	5 62
6	6 24	6 48	6 74
7	7 28	7 57	7 87
8	8 32	8 65	8 99
9	9 36	9 73	10 12
10	10 40	10 81	11 24
20	20 80	21 63	22 49
30	31 20	32 44	33 74
40	41 60	43 26	44 99
50	52 00	54 08	56 24
60	62 40	64 89	67 49
70	72 80	75 71	78 74
80	83 20	86 52	89 98
90	93 60	97 34	101 23
100	104 00	108 16	112 48
200	208 00	216 32	224 97
300	312 00	324 48	337 45
400	416 00	432 64	449 94
500	520 00	540 80	562 43
600	624 00	648 96	674 91
700	728 00	757 12	787 40
800	832 00	865 28	899 89
900	936 00	973 44	1,012 37
1,000	1,040 00	1,081 60	1,124 86
2,000	2,080 00	2,163 20	2,249 72
3,000	3,120 00	3,244 80	3,374 59

Barême Universel (Paris, 1822), pp. 382-390.

	LAW SCHOOL APTITUDE TEST (LSAT) PERCENTILE								
GPA	0-30	31-40	41-50	51-60	61-70	71-80	81-90	91-99	TOTALS
>3.75	7-0	7-0	13-3	18-0	34-1	71-9	151-36	449-345	750-394
3.75	21-1	26-4	38-6	54-0	94-0	206-14	358-19	791-436	1588-480
3.50	57-4	37-4	53-5	65-2	136-5	228-8	369-6	798-148	1743-182
3.25	88-0	59-5	61-0	96-5	131-8	193-7	289-12	504-44	1421-81
3.00	93-0	46-0	46-0	53-0	79-1	89-3	122-2	204-7	732-13
<2.75	174-0	55-0	44-0	51-0	53-0	74-0	80-0	113-2	644-2
TOTALS	440-5	230-13	255-14	337-7	527-15	861-41	1369-75	2859-982	6878-1152

Law School Admission Council and the Association of American Law Schools, *Pre-Law Handbook 1983-84* (Washington, D.C., 1983). The table shown is for the School of Law, New York University. Redrawn.

Small multiples work as efficient and convincing summaries of data or an argument, making the same point again and again by offering complementary variations on the major substantive theme. Here is the colorful story of one such chart:

The New York Times, March 14, 1987, p. 1.

GOTTI IS ACQUITTED BY A FEDERAL JURY IN CONSPIRACY CASE

NEW CHARGES ARE LIKELY

Verdict is the First Setback in Recent Government Drive Against Mafia Leaders

By LEONARD BUDER

John Gotti was acquitted of Federal racketeering and conspiracy charges yesterday in the Government's first major setback in its recent assault on organized crime.

Mr. Gotti, who the Government says is the leader of the nation's most powerful Mafia family, and six co-defendants were found not guilty of charges they took part in a criminal enterprise. They were accused of carrying out illegal gambling and loan-sharking operations, armed hijackings and at least two murders over an 18-year period.

Despite yesterday's verdict, Federal investigators said the 46-year-old Mr. Gotti might face indictment on new charges as head of the Gambino crime family. "I can't comment but I won't deny it," said Thomas L. Sheer, head of the Federal Bureau of Investigation in New York, when asked if the F.B.I. was building up another case against Mr. Gotti.

'We'll Be Starting Again'

"They'll be ready to frame us again in two weeks," Mr. Gotti told a reporter before leaving the Brooklyn courthouse in a gray Cadillac that was waiting for him. "In three weeks we'll be starting again, just watch."

Until yesterday, Federal prosecutors in the Southern and Eastern Districts of New York had recorded a string of successes in major organized-crime cases.

Within the last six months, the heads of the city's four other Mafia families have been convicted after trials in Manhattan and Brooklyn. They, like Mr. Gotti and his co-defendants, had been charged under the Federal Racketeer Influenced and Corrupt Organizations Act, or RICO.

Key Witnesses Were Criminals

"Obviously they perceived there was something wrong with the evidence," said Andrew J. Maloney, the United States Attorney in Brooklyn, referring to the jury.

Many of the Government's key witnesses were criminals who testified for the prosecution under grants of immunity or in return for payments and other benefits.

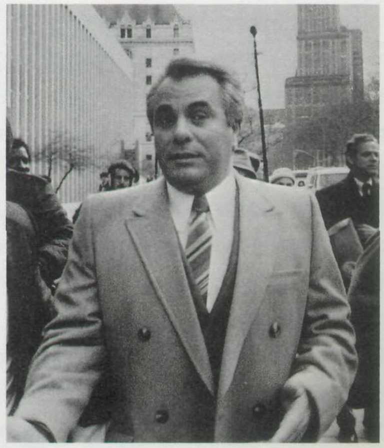
The last piece of evidence requested by the jury for re-examination was a chart introduced by the defense that showed the criminal backgrounds of seven prosecution witnesses. It listed 69 crimes, including murder, drug possession and sales and kidnapping.

Mr. Gotti's lawyer, Bruce Cutler, said the jury showed "courage" because "it's not easy to say no to a Federal prosecutor." He said the jury had not been impressed with the testimony of "paid Government informants who lie, who use drugs, who kill people."

The verdict, which came on the seventh day of jury deliberations after a trial that lasted almost seven months, surprised many in the packed courtroom. Friends of the defendants cheered and applauded; the Government prosecutors, Diane F. Giacalone and John Gleeson, looked glum.

Mr. Gotti, who has been dubbed "Dapper Don" because of his expensive attire and impeccable grooming, and his co-defendants hugged and kissed each other and their lawyers.

Then they stood and applauded as the 12 members of the jury — whose identities had been kept secret to prevent possible tampering — left the room escorted by Federal marshals....



The New York Times

John Gotti

A Weakness In Gotti Case

Major U.S. Witnesses Viewed as Unreliable

By SELWYN RAAB

News Analysis

Many lawyers and prosecutors who followed events in the seven-month trial of John Gotti said the underlying weakness of the prosecution's case was its apparent reliance on turncoat career criminals as key witnesses against Mr. Gotti and six co-defendants.

A signal that the credibility of the prosecution's principal witnesses was in doubt came yesterday morning when the jury, in its final request before acquitting the defendants of all charges, reviewed an exhibit introduced by the defense.

It was a chart listing the lengthy criminal records of seven prosecution witnesses who had obtained promises of leniency and other favors from the Government in return for their testimony against Mr. Gotti....

The chart invites reading both horizontally and vertically; neither direction enhances the reputations of those testifying against Mr. Gotti and his colleagues, as the eye detects curious patterns and unbroken runs of X's. Mr. Polisi, for example, has something of a streak going. Those marks indicating each crime by each witness are not modest or shy, and they dominate the spreadsheet grid (although only 37 percent of all the possible combinations are marked). Placement of particularly obnoxious activities at the top (murder) and bottom of the list (pistol whipping a priest) exploits the visual prominence of those positions.

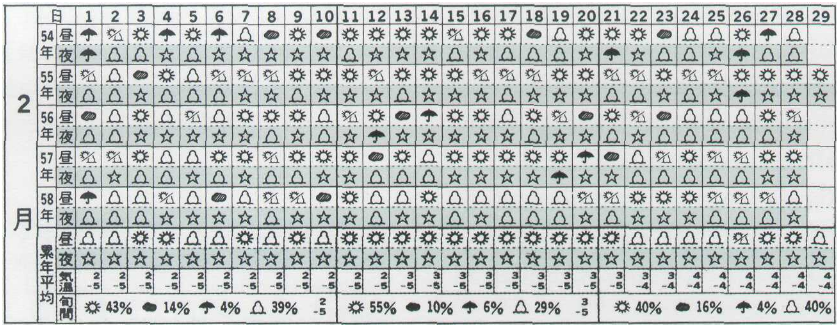
United States v. Gotti, et al, 1987. Chart supplied by counsel, Bruce Cutler and Susan G. Kellman.

CRIMINAL ACTIVITY OF GOVERNMENT INFORMANTS

CRIME	CARDINALE	LOFARO	MALONEY	POLISI	SENATORE	FORONJY	CURRO
MURDER	X	X					
ATTEMPTED MURDER		X	X				
HEROIN POSSESSION AND SALE	X	X		X			X
COCAINE POSSESSION AND SALE	X		X	X			
MARIJUANA POSSESSION AND SALE							X
GAMBLING BUSINESS		X		X		X	
ARMED ROBBERIES	X		X	X	X		X
LOANSHARKING		X		X			
KIDNAPPING			X	X			
EXTORTION			X	X			
ASSAULT	X		X	X			X
POSSESSION OF DANGEROUS WEAPONS	X	X	X	X	X		X
PERJURY		X				X	
COUNTERFEITING					X	X	
BANK ROBBERY			X	X			
ARMED HIJACKING				X	X		
STOLEN FINANCIAL DOCUMENTS			X	X	X		
TAX EVASION				X		X	
BURGLARIES	X	X		X	X		
BRIBERY		X		X			
THEFT: AUTO, MONEY, OTHER			X	X	X	X	X
BAIL JUMPING AND ESCAPE			X	X			
INSURANCE FRAUDS					X	X	
FORGERIES				X	X		
PISTOL WHIPPING A PRIEST	X						
SEXUAL ASSAULT ON MINOR							X
RECKLESS ENDANGERMENT							X

Such displays are likely to be especially persuasive and memorable in situations where most information communicated consists of spoken words—as in a trial.[19] Courtroom graphics can overcome the linear, nonreversible, one-dimensional sequencing of talk talk talk, allowing members of a jury to reason about an array of data at their own pace and in their own manner. Visual displays of information encourage a diversity of individual viewer styles and rates of editing, personalizing, reasoning, and understanding. Unlike speech, visual displays are simultaneously a wideband and a perceiver-controllable channel.

[19] For visual displays in the courtroom, see Larry Gillen, ed., *Photographs and Maps Go to Court* (Washington, D.C.: American Society for Photogrammetry and Remote Sensing, 1986); and Gregory P. Joseph, *Modern Visual Evidence* (New York, 1989).



sunny day

starry night

cloudy

rain

snow

This weather history above extends the technique, partitioning data by town, year, month, day, and day/night. Here are five years of daily and nightly Tokyo weather every day in February. Bottom rows report summary data, averaged over ten-day periods, recounting the (1) most frequently observed weather, 1967-1982; (2) average high and low temperatures, last 30 years, 1951-1980; and (3) daytime frequency of sunshine, clouds, and rain during the last 16 years. A splendid total of 414 pieces of data are smoothly entabled, conveying both a sense *of average* and *of variation* about that average—the two fundamental summary measures of statistical data.

Redrawn from *Weather Chart, 1984* (Tokyo, 1985), p. 42.

Redrawn from *Kisho Nenkan 1984 [The 1984 Meteorological Almanac]*, The Meteorology Agency and Japan Meteorology Association (Tokyo, 1984), pp. 134-135.

An even more concentrated history, below, of Tokyo climate divides a full decade of observations by town, year, month, and day. Especially adroit is the gathering of both dimensions of the paper to apportion the one-dimensional variable, time, into increments from fine to coarse; each year-by-day-matrix is compounded by months, stretching the range of a compact display into an abundant span of 1,826 days of weather history. High-information graphics, such as this, convey a spirit of quantitative depth and a sense of statistical integrity. Emaciated data-thin designs, in contrast, provoke suspicions—and rightfully so—about the quality of measurement and analysis.

○ Clear. Average amount of clouds less than 15% for all day (3:00, 9:00, 15:00, 21:00).

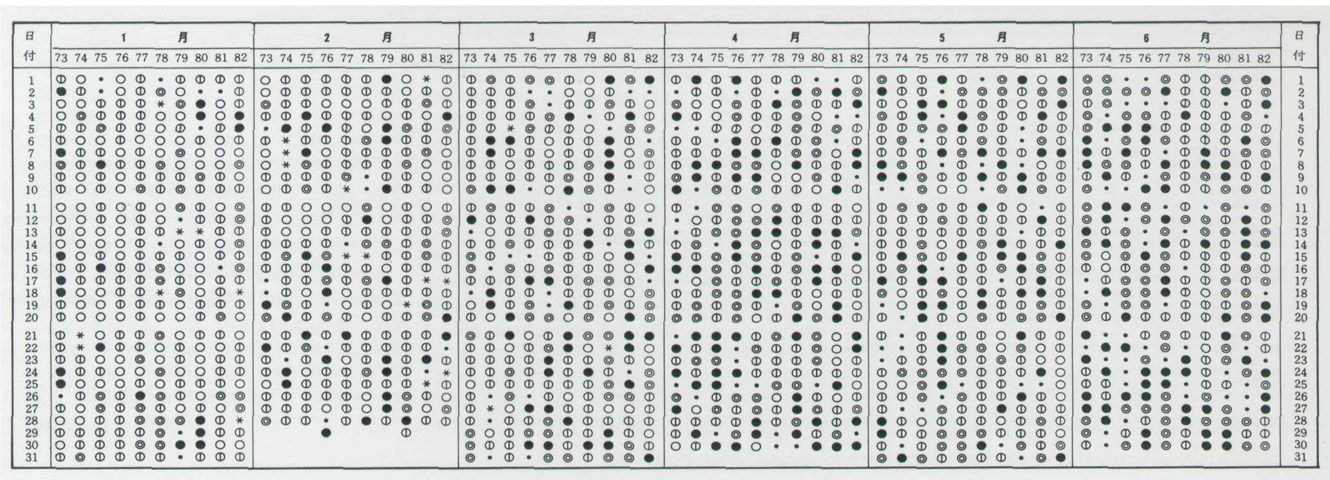
⦶ Fair. Average amount of clouds more than 15% and less than 84% for all day.

◎ Cloudy. Average amount of clouds more than 85%.

• Light rain. Rain more than I mm but less than 5 mm.

● Rain. More than 5 mm in 24 hours.

∗ Snow. More than 1 cm during day.



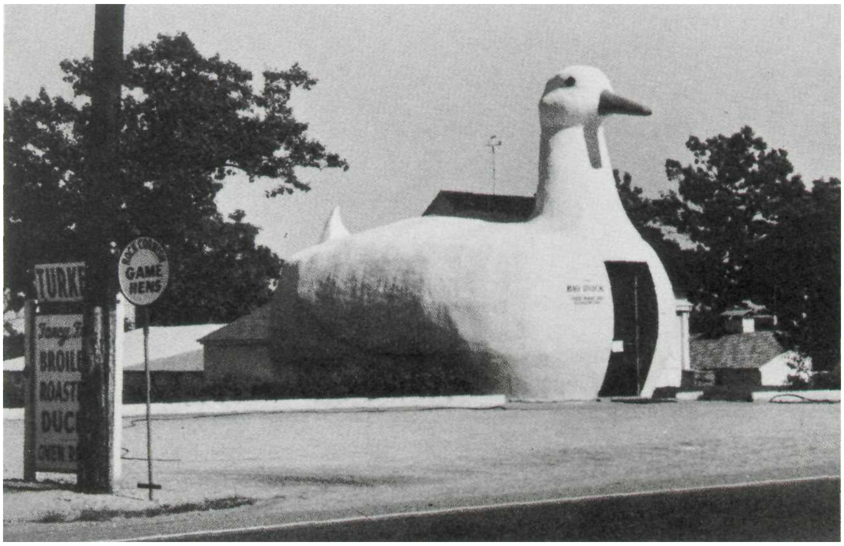
Redrawn from Yumi Takahashi and Ikuyo Shibukawa, *Color Coordination* (Tokyo, 1985), pp. 114-115.

Small multiples, whether tabular or pictorial, move to the heart of visual reasoning - to see, distinguish, choose (even among children's shirts). Their multiplied smallness enforces local comparisons within our eyespan, relying on an active eye to select and make contrasts rather than on bygone memories of images scattered over pages and pages.

We envision information in order to reason about, communicate, document, and preserve that knowledge — activities nearly always carried out on two-dimensional paper and computer screen. Escaping this flatland and enriching the density of data displays are the essential tasks of information design. Such escapes grow more difficult as ties of data to our familiar three-space world weaken (with more abstract measures) and as the number of dimensions increases (with more complex data). Still, all the history of information displays and statistical graphics — indeed of any communication device — is entirely a progress of methods for enhancing density, complexity, dimensionality, and even sometimes beauty. Some of these methods, identified and described in the chapters that follow, include micro/macro readings of detail and panorama, layering and separation of data, multiplying of images, color, and narratives of space and time.

By giving the focus over to data rather than data-containers, these design strategies are transparent and self-effacing in character. Designs so good that they are invisible. Too many data presentations, alas, seek to attract and divert attention by means of display apparatus and ornament. Chartjunk has come to corrupt all sorts of information exhibits and computer interfaces, just like the "ducks" of modern architecture:

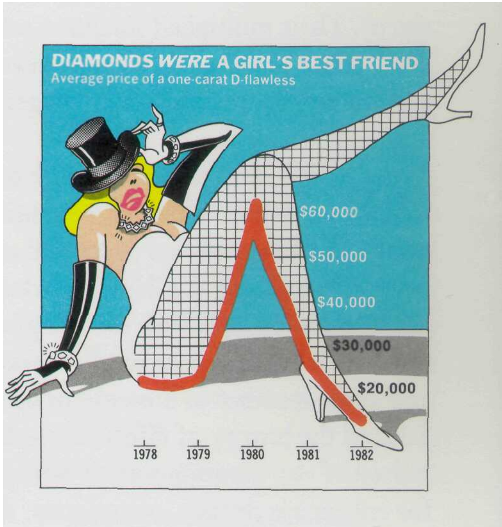
> When Modern architects righteously abandoned ornament on buildings, they unconsciously designed buildings that *were* ornament. In promoting Space and Articulation over symbolism and ornament, they distorted the whole building into a duck. They substituted for the innocent and inexpensive practice of applied



Peter Blake, *God's Own Junkyard* (New York, 1964, 1979), p. 101.

[20] Robert Venturi, Denise Scott Brown, and Steven Izenour, *Learning from Las Vegas* (Cambridge, 1977), p. 163.

> decoration on a conventional shed the rather cynical and expensive distortion of program and structure to promote a duck.... It is now time to reevaluate the once-horrifying statement of John Ruskin that architecture is the decoration of construction, but we should append the warning of Pugin: It is all right to decorate construction but never construct decoration.[20]



Consider this unsavory exhibit at right—chockablock with cliche and stereotype, coarse humor, and a content-empty third dimension. It is the product of a visual sensitivity in which a thigh-graph with a fishnet-stocking grid counts as a Creative Concept. Everything counts, but nothing matters. The data-thin (and thus uncontextual) chart mixes up changes in the value of money with changes in diamond prices, a crucial confusion because the graph chronicles a time of high inflation.

Lurking behind chartjunk is contempt both for information and for the audience. Chartjunk promoters imagine that numbers and details are boring, dull, and tedious, requiring ornament to enliven. Cosmetic decoration, which frequently distorts the data, will never salvage an underlying lack of content.[21] If the numbers are boring, then you've got the wrong numbers. Credibility vanishes in clouds of chartjunk; who would trust a chart that looks like a video game?[22]

Worse is contempt for our audience, designing as if readers were obtuse and uncaring. In fact, consumers of graphics are often more intelligent about the information at hand than those who fabricate the data decoration. And, no matter what, the operating *moral* premise of information design should be that our readers are alert and caring; they may be busy, eager to get on with it, but they are not stupid. Clarity and simplicity are completely opposite simple-mindedness. Disrespect for the audience will leak through, damaging communication. What E. B. White said of writing is equally true for information design: "No

[21] For detailed evidence, see Edward R. Tufte, *The Visual Display of Quantitative Information* (Cheshire, Connecticut, 1983), pp. 52-87.

[22] Paul Rand writes, "Readers of a report should be unaware of its 'design.' Rather, they should be enticed into reading it by interesting content, logical arrangement and simple presentation. The printed page should appear natural and authoritative, avoiding gimmicks which might get in the way of its documentary character." Paul Rand, "Design," in *Speaking Out on Annual Reports* (New York, 1983).

one can write decently who is distrustful of the reader's intelligence, or whose attitude is patronizing."[23]

Standards of excellence for information design are set by *high quality maps,* with diverse bountiful detail, several layers of close reading combined with an overview, and rigorous data from engineering surveys. In contrast, the usual chartjunk performances look more like posters than maps. Posters are meant for viewing from a distance, with their strong images, large type, and thin data densities. Thus poster design provides very little counsel for making diagrams that are read more intensely. Display of closely-read data surely requires the skilled craft of good graphic and poster design: typography, object representation, layout, color, production techniques, and visual principles that inform criticism and revision. Too often those skills are accompanied by the ideology of chartjunk and data posterization; excellence in presenting information requires mastering the craft and spurning the ideology.[24]

THE ducks of information design are *false escapes from flatland,* adding pretend dimensions to impoverished data sets, merely fooling around with information. They don't work, just as this royal dining table, caught up in flatland, fails to hold the pots and plates. The king and queen watch in exasperation and exclaim, as their meal slides off, "It's the way they draw these wretched tables!"

[23] William Strunk, Jr. and E. B. White, *The Elements of Style* (New York, 1959), p. 70. An effective trial lawyer, Joe Jamail, noted "If you use too many pictures and make it like a circus or going to a matinee, jurors will think you think they're stupid." Susan Ayala, "Legal-Graphics Firms," *The Wall Street Journal, July 21, 1*988, p. 19.

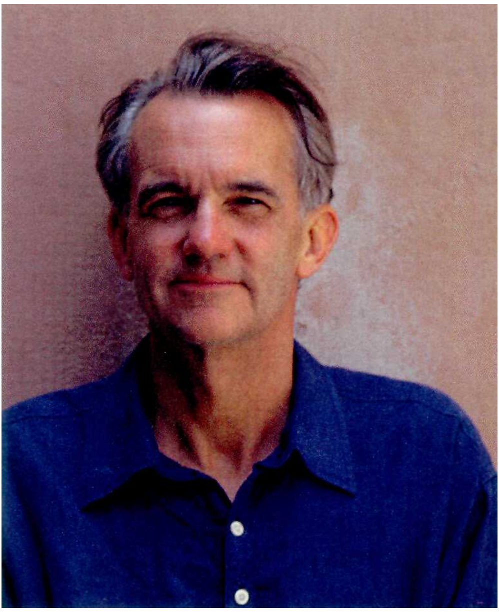
[24] Our philosophy of information design—self-effacing displays intensely committed to rich data—parallels Balanchine's approach to dance. Lincoln Kirstein, in his 1972 essay "Balanchine's Fourth Dimension," describes an attitude governing the nature of dancing: "A committed Balanchine dancer (with a small 'd') comes to realize that Personality (with an enormous 'P') is a bundle of haphazard characteristics frozen in a pleasing mask for immediate identification and negotiable prestige. No matter what is danced—and it makes little difference—stardom dims the dancing. What is danced is perforce secondary. There are two types of ballet companies: those interested in selling stars and those occupied in demonstrating and extending the dance, as such. . . . Physicality in the tense relationships of Balanchine's dancers kept under so strict a discipline in so free an exercise pushes the spectacle to a high pressure point. Everything is so focused, compressed, packed, playful that it is as if the entire design were patterned on coiled steel or explosive fuels. Combinations of music in motion approach a fourth dimension that cannot be verbally defined." *Vogue,* 160 (December 1972), 118-129, 203-206; and Lincoln Kirstein, *Ballet: Bias and Belief (New* York, 1983), 111-119.

Harvey, *The Bulletin,* Sydney, Australia, ca. 1950s, as reproduced in E. H. Gombrich, *The Image and the Eye* (Oxford, 1982), p. 21.

Edward Tufte is a professor at Yale University, where he teaches courses in statistical evidence and information design. His books include *Visual Explanations: Images and Quantities, Evidence and Narrative, Envisioning Information, The Visual Display of Quantitative Information, Political Control of the Economy, Data Analysis for Politics and Policy,* and *Size and Democracy* (with Robert A. Dahl).

He is a fellow of the American Statistical Association, the American Academy of Arts and Sciences, the Guggenheim Foundation, and the Center for Advanced Study in the Behavioral Sciences. He has received honorary doctorates from The Cooper Union and Connecticut College, the Phi Beta Kappa Award in Science, and the Joseph Rigo Award for contributions to software documentation from the Association for Computing Machinery.

Envisioning Information has received 14 awards for content and design, including the Phi Beta Kappa Award in Science and "Best Graphic Design of the Year" from *International Design.*



photograph by Inge Druckrey, Rome 1997