Bertin’s theory of data visualization

Mick McQuaid

Semiology of graphics

Jacques Bertin’s landmark book presents a theory of what we now call data visualization but which Bertin referred to as graphics. His theory is a “sign-system” of graphics. Semiology is the study of sign-systems.

Sign systems and their meanings

meaning	sound	sight
monosemic	math	graphics
polysemic	language	figurative imagery
pansemic	music	abstract imagery

Graphics are a visual, spatial system

Graphics have at their disposal the variation of marks and the two dimensions of a plane as visual variables.

The relationships between these visual variables can be perceived instantaneously. In contrast, a linear system such as speech requires an instant for each sound.

Analysis of the information

The information to be transmitted is *content*. The graphic system is its *container*.

Bertin uses the expression *translatable content of a thought* to characterize information.

Sidebar: Persuasive graphics

Bertin is not at all concerned with persuasion. A contemporary researcher, B J Fogg, focuses on persuasive graphics. Bertin is only concerned with the limits of the sign-system. *Does a given graphic convey what it means to convey?* That is the question to be answered with Bertin's theory. Whether the graphic is truthful or misleading is a separate question, outside the definition of the sign-system.

Information has variation

The *invariant* is whatever is common to all correspondences in information. The variational concepts in information are the *components*.

These two terms, invariant and component, are key to understanding the theory. You can think of the invariant as the title of a given data visualization, the thing that summarizes the entirety of it. The components, on the other hand, are the things that vary in a given visualization.

In a stock price chart, the stock is the invariant and the price and time are components.

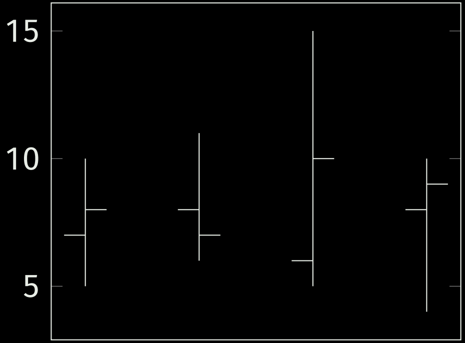
Starting the analysis of information

The very first step in analysis is to determine the number of components.
This is because the eye can only distinguish a small number of variables.

Components are not variables

The components are the content of the information that varies, such as a price or date. The variables are the visible marks used to represent the components.

Here is a hi-lo open-close stock price chart for four days.



Both components and variables have length

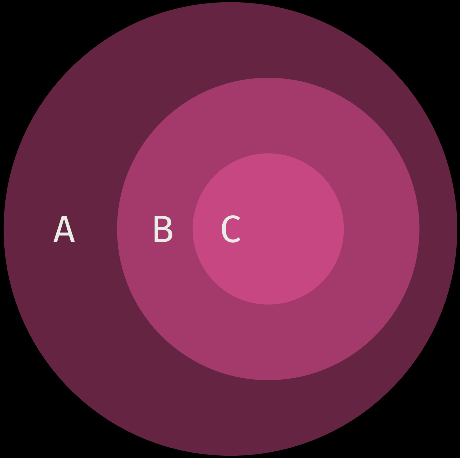
Length is a property of both components and variables. It is the number of categories of the component or variable.

For example, state is a component in a picture of the USA and it has length 50. On a primitive computer display, the color is a retinal variable and has length 16.

Levels of organization

Every component is located on one of three overlapping levels

- A quantitative or interval-ratio level, using countable units
- B ordered level involves all concepts permitting a ranking
- C qualitative or nominal level includes all unordered groupings



Properties of the graphic system

Bertin avoids time, eliminating animation from the scope of the graphic system. Its realm is only what can be perceived in an instant.

Eight variables are within scope

- Two dimensions of the plane
- size
- value
- texture
- color
- orientation
- shape

Marks on the plane

Each mark signified by the eight variables can represent

- a point
- a line
- an area

Each graphic is one of three kinds

- a diagram, depicting correspondences between two or more components, as in a picture of stock price over time
- a network, depicting correspondences within a component, as in a network of conversations between individuals
- a map, depicting correspondences among elements of a geographic component, such as a map of dairy production among states of the USA

The six retinal variables

- size
- value
- texture
- color
- orientation
- shape

The basic graphic problem

so many choices!

A basis for choice between many possible graphics

If, in order to obtain a correct and complete answer to a given question, all other things being equal, one construction requires a shorter period of perception than another construction, we can say that it is more *efficient* for this question.

Five aspects of image theory

1. Stages in the reading process
2. Possible questions—levels of reading
3. Definition of an image
4. Construction of an image
5. Limits of an image

1. Stages in the reading process

- external identification: what components are involved?
- internal identification: by what variables are the components expressed?
- perception of pertinent correspondences: what are the pertinent correspondences between components, e.g., what is the given stock price at a particular moment?

2. Possible questions—levels of reading

- questions introduced by one element of a component, resulting in a single correspondence—the elementary level
- questions introduced by a group of elements in a component—the intermediate level, reducing the length of the components
- questions introduced by the entire component—the overall or global level, reducing all information to a single ordered relationship

2. Possible questions—levels of reading, continued

- there are as many types of questions as components
- for each type there are three levels of reading
- each question can be defined by its type and level

3. Definition of an image

The meaningful visual form perceptible in the minimum instant of vision is an image. The most *efficient* constructions are those in which any question can be answered in a single *image*.

The image is not the same thing as the figure, which includes everything seen in a frame. A single figure may include many images, not necessarily as separate constructions but with individual instants of perception.

4. Construction of an image

The image is built upon three homogeneous and ordered variables: the two dimensions of the plane and a retinal variable.

All information with three components or fewer can be represented as a single image.

5. Limits of an image

An image will not accommodate more than three meaningful variables. All information with more than three components can not be constructed as an image. It is necessary then to choose preferred questions and construct the graphic so that they can be answered in a single instant of perception.

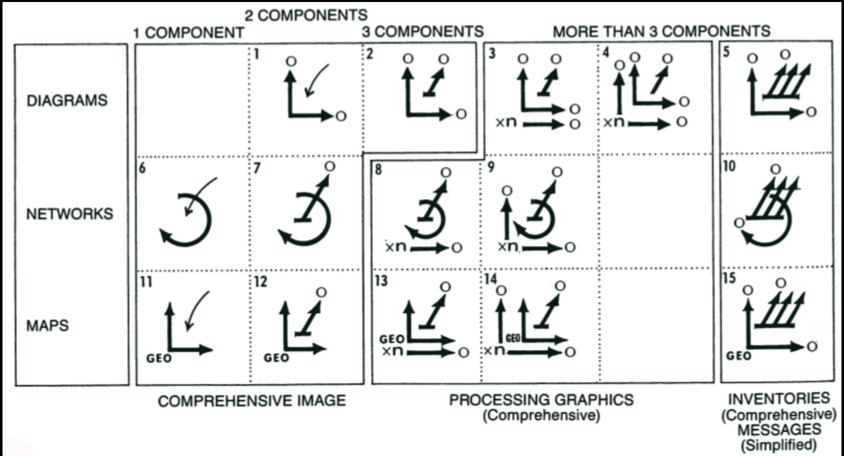
Functions of graphic representation

1. Recording information: creating a storage mechanism to avoid memorization
2. Communicating information: creating a memorizable image to inscribe the information in the viewer's mind
3. Processing information: permitting a simplification and its justification

Rules of construction

The rules to define the most efficient construction for a given case are represented by the standard schemas, shown on the next slide.

Standard schemas



Bertin's graphical notation

The diagram on the preceding slide comes from page 172 of Bertin's book and uses Bertin's notation to depict what he calls the *standard schemas*. These are the schemas that represent the ideal combinations of visual variables to depict different kinds of information. Notice that elements are additive in the horizontal direction for each kind of imposition. You need to consult the table on pages 56 and 57 of Bertin's book to fully appreciate them. The letter O, for example, means ordered, and suggests that in most cases visual variables capable of ordering are required. The orthogonal arrows mean that the planar dimensions are required, while the circular arrow signifies that a network arrangement, e.g., spokes of a wheel, is required. The diagonal arrow means *elevation above the plane* and refers to the six retinal variables. The variable *n* signifies that at least *n* images are required in a figuration.

Rules of legibility

The rules of construction govern the choice of visual variables but they can still be used well or poorly. So we need rules of legibility arising from the need to accomplish sensory differentiation. These fall into three categories

- graphic density
- angular separation
- retinal separation

Graphic density

Bertin distinguishes between figurations (what is seen) and images (a meaningful visual form perceptible in the minimum instant of vision) and contends that there is an optimum number of marks per square centimeter (ten is the maximum number) for a figuration. Yet there is no upper bound for an image because of its definition as instantly perceptible.

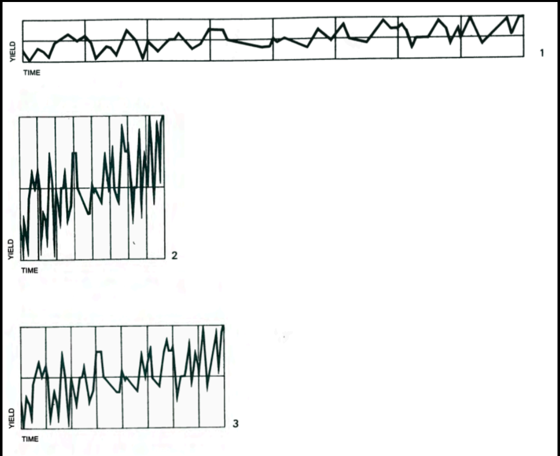
Too few marks per square centimeter represents an underutilization of the graphic capacity.

Angular legibility

Angular legibility results from a compromise between two potentially contradictory rules:

- on the elementary level, optimum angular legibility is located near 70 degrees
- on the overall level, the image tends toward the form of a square where optimum angular legibility is provided by the diagonal

Angular legibility example

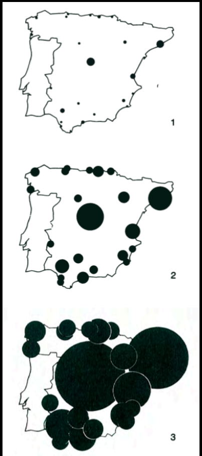


Angular legibility example, described

- Figure 1 in the preceding slide is too flat for the overall trend to be apparent but is ideal for elementary readings of individual yields at different points in time
- Figure 2 in the preceding slide is ideal for showing the overall trend but the angles are too severe to read at the elementary level
- Figure 3 is a compromise between figures 1 and 2

Retinal legibility

The total amount of black should vary between 5 and 10 percent, as in figure 2. Figure 1 has insufficient black and figure 3 has too much.



Retinal legibility: contrast between figure and ground

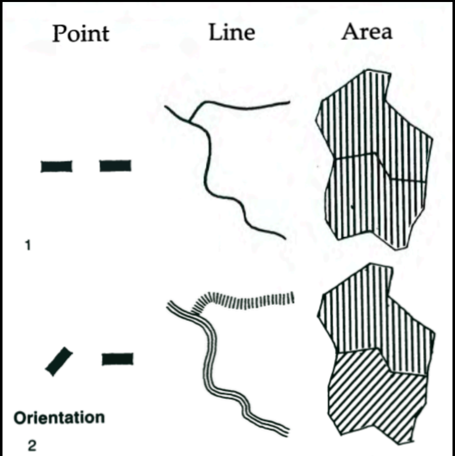
The subject matter must be separated from the background as in figure 5, not figure 4.

Retinal legibility: quantitative perception

Quantitative perception depends on the utilization of the maximum range (ratio of the smallest to largest signs) in a series based on size differences.

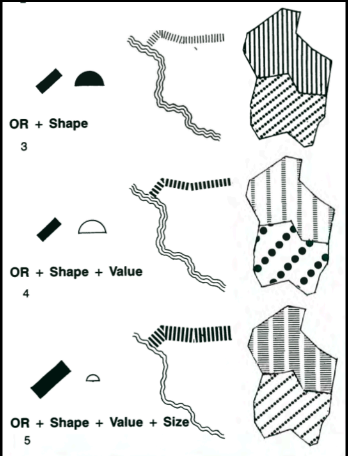
Retinal legibility: selective perception

Selective perception is augmented by combinations of retinal variables, starting on this slide and continuing on the next.



Retinal legibility: selective perception, continued

Selective perception is augmented by combinations of retinal variables, starting on the previous slide and continuing here.



Summary

We have described the vocabulary for some of Bertin’s theory, and glanced at the rules for the construction and reading of efficient graphics for answering specified questions.