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**The language of graphics**

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# Analyzing Graphic Representations and Graphic Theories

## 5.1 Analysis of Graphic Representations

Now that we have completed the discussion of the proposed framework, we can apply it by 'trying it out' on example specimen of graphics. We claim that we can provide any graphic representation with an analysis in terms of the framework. Instead of grouping such example analyses here in this section, we have decided to distribute these throughout the thesis. In other words, all 'boxed' example figures in the thesis have been provided with a figure caption that follows a standardized analysis scheme, applying the proposed framework. A visual overview of the figures is given in the Figure Index towards the end of the thesis.

The standardized figure caption starts with a brief description of **What is shown** by the figure, followed by a note on the **Source** of the figure, and a **Comment**, which serves to point out some specific aspect of the figure. This is followed by a standardized analysis scheme, which includes three main items:

- **Syntax of spatial structure:** a brief analysis of the figure in terms of the concepts presented in the section on 'Syntactic structures' (2.5).
- **Type of correspondence:** a brief analysis of the figure, usually split into 'Spatial structure' and 'Visual attributes', in terms of the concepts presented in the section on 'Type of correspondence' (3.1).

- **Type of graphic representation:** an assessment of the figure in terms of the general categories presented in the chapter on 'Classification of graphic representations' (4).

Most of the specific terms that are used in the figure captions can be looked up in the Glossary at the very end of this thesis.

## 5.2 Analysis of Graphic Theories

The framework that is developed in this thesis does not only enable the analysis of graphic representations, but it also enables the analysis and comparison of existing graphic theories.

In this section, 'terminology translations' are provided for various existing graphic theories, sorted alphabetically by author. The terms used by the concerned author are given between single quotes, and are translated into the corresponding terms from the framework developed in this thesis, which are given in *italics*. The latter terms can be looked up in three places in this thesis: in the Glossary, in the Subject Index, and in the (sub)sections that are given in parentheses after each 'translation'.

For most of the mentioned authors, brief discussions of their concepts can be found throughout the preceding chapters; see the separate Author Index towards the end of the thesis.

Some of the summaries below include a brief note concerning one or more concepts that seem to be missing in the context of the analysis proposed by the concerned author.

**Arnheim** (1969) makes a distinction between three possible functions that an image may have. It may be a 'picture', a 'symbol', or a 'sign':

- 'picture' ≈ a *literal* graphic object (3.1.1).
- 'symbol' ≈ a *metaphoric* graphic object (3.1.2).
- 'sign' ≈ an *arbitrary-conventional* graphic object (3.1.5).

Missing concept in this context: a *metonymic* (3.1.3) graphic object.

Arnheim also discusses the 'abstraction level of the image':

- 'realistic' ≈ *realistic* (3.2).
- 'stylized' ≈ *schematic* (3.2).
- 'non-mimetic' ≈ *abstract* (3.2).

**Barthes** (1965) distinguishes between 'iconic', 'motivated', and 'arbitrary' signs:

- 'iconic' signs ≈ *literal* (3.1.1) graphic objects.
- 'motivated' signs ≈ *metaphoric* (3.1.2), *metonymic* (3.1.3), and *rebus-based* (3.1.4) graphic objects.
- 'arbitrary' signs ≈ *arbitrary-conventional* (3.1.5) graphic objects.

**Bertin** (1967, 1977) is best known for his inventory and study of:

- 'visual variables'  $\approx$  *visual attributes* (2.4).

Bertin divides graphic representations into four 'groups of imposition':

- 'map'  $\approx$  *map* (4).
- 'diagram'  $\approx$  *statistical chart* and/or *time chart* (4).
- 'network'  $\approx$  *link diagram* (4).
- 'symbol'  $\approx$  *symbol* (4).

Concerning the 'amount of black' in a graphic, Bertin makes a distinction between 'subject matter' and 'background':

- 'subject matter'  $\approx$  *information objects* (3.3).
- 'background'  $\approx$  *spatial reference objects* (3.3).

To show complex collections of data, Bertin promotes using a:

- 'collection of images' = a *graphic multiple* (2.5.4).

**Bowman** (1968) distinguishes different types of 'visual translation':

- 'objective'  $\approx$  *realistic* (3.2).
- 'associative'  $\approx$  *schematic* (3.2).
- 'conventional'  $\approx$  *abstract* (3.2).
- 'abstract'  $\approx$  a graphic representation that expresses a conceptual structure through *metaphoric* (3.1.2) *graphic relations* (2.1) between graphic objects.

Bowman also introduces the concept of:

- 'multi-plane space'  $\approx$  a *graphic space* with several *visual layers* (2.2).

**Card, Mackinlay and Shneiderman** (1999) approach 'visual structures' as consisting of:

- 'spatial substrate'  $\approx$  *graphic space* (2.2).
- 'marks'  $\approx$  *elementary graphic objects* (2.3).
- 'graphical properties'  $\approx$  *visual attributes* (2.4).

They distinguish four different 'types of axes':

- 'unstructured axis'  $\approx$  an *unstructured dimension* (2.5.2).
- 'nominal axis'  $\approx$  an *unordered lineup* or an *unordered separation* (2.5.1).
- 'ordinal axis'  $\approx$  an *ordered lineup* or an *ordered separation* (2.5.1).
- 'quantitative axis'  $\approx$  a *metric dimension* (2.5.2).

Concerning 'topological structure', Card et al. note two possibilities:

- 'connection'  $\approx$  *linking* (2.5.1).
- 'enclosure'  $\approx$  *containment* (2.5.1).

As special techniques for spatial encoding they briefly mention:

- 'composition'  $\approx$  *simultaneous combination* (2.5.4) of orthogonal dimensions.
- 'alignment'  $\approx$  *shared-axis multipanel* (2.5.4).
- 'recursion'  $\approx$  *nesting* (2.5.4) into a *separation* or a *lineup* (2.5.1).
- 'overloading'  $\approx$  *nesting* (2.5.4) into a *metric space* (2.5.2).

Missing concepts in this context: *proportional division* (2.4), *proportional repetition* (2.5.1), *integral versus composite metric space* (2.5.2), *graphic multiples* (2.5.4).

**Horn** (1998) distinguishes three types of 'morphological elements of visual language':

- 'image'  $\approx$  *pictorial object* (3.2).
- 'shape'  $\approx$  *abstract shape* (3.2).
- 'word'  $\approx$  *word* (3.2).

Concerning the arrangement of elements, Horn lists six types of 'topologies' or 'syntactical structures':

- 'proximity grouping'  $\approx$  *spatial clustering* (2.5.1).
- 'network'  $\approx$  *linking* (2.5.1).
- 'boundary'  $\approx$  *separation by a separator* (2.5.1).
- 'concentric'  $\approx$  *meaningful space with a radial dimension* (2.5.2).
- 'level'  $\approx$  *horizontal separation or horizontal lineup* (2.5.1).
- 'matrix'  $\approx$  *simultaneous combination* (2.5.4) of a *horizontal separation* and a *vertical separation* (2.5.1).

Missing concepts in this context: *metric axes* (2.5.2), *metric spaces* (2.5.2), *nesting* (2.5.4) and the possible *recursive nature* (2.1) of syntactic structures.

**Knowlton** (1966) distinguishes three 'parts' of a graphic representation - 'elements', their 'pattern of arrangement', and their 'order of connection':

- 'elements'  $\approx$  *elementary graphic objects* (2.3).
- 'pattern of arrangement'  $\approx$  *positioning in graphic space* (2.2 and 2.5).
- 'order of connection'  $\approx$  *linking* (2.5.1).

Missing concepts in this context: other types of object-to-object relations such as *containment* (2.5.1).

According to Knowlton, each of the 'parts' mentioned above may be 'iconic', 'analogical', or 'arbitrary':

- 'iconic'  $\approx$  *literal* (3.1.1).
- 'analogical'  $\approx$  *metaphoric* (3.1.2).
- 'arbitrary'  $\approx$  *arbitrary-conventional* (3.1.5, for graphic objects) or *arbitrary* (2.5, for graphic relations).

Missing concepts in this context: *metonymic graphic objects* (3.1.3).

**Kosslyn** (1994) divides graphic representations into four types:

- 'diagrams'  $\approx$  *pictures* (4).
- 'maps'  $\approx$  *maps* (4).
- 'charts'  $\approx$  *link diagrams* (4).
- 'graphs'  $\approx$  *statistical charts* (4).

He distinguishes two types of multipanel displays:

- 'pure multipanel display' = *graphic multiple* (2.5.4).
- 'mixed multipanel display' = *multipanel display* (2.5.4).

**Krampen** (1965) distinguishes three 'kinds of graphic signs':

- 'pictograph' ≈ *picture* (3.2).
- 'diagram' ≈ *abstract shape* (3.2).
- 'phonogram' ≈ *word* (3.2).

**Lakoff** (1987) proposes 'image schemata' which he believes play a crucial role in human cognition. These include:

- 'linear order schema' ≈ *lineup* (2.5.1).
- 'link schema' ≈ *linking by a connector* (2.5.1).
- 'container schema' ≈ *containment by a container* (2.5.1).
- 'front-back schema' ≈ *superimposition* (2.5.1).

**Lohse et al.** offer a classification of graphic representations into:

- 'graphs' ≈ *statistical charts* (4).
- 'time charts' ≈ *time charts* (4).
- 'network charts' ≈ *link diagrams* (4).
- 'maps' ≈ *maps* (4).
- 'cartograms' ≈ *statistical maps* (4).
- '(graphic) tables' ≈ *tables* (4).
- 'pictures', 'structure diagrams', and 'process diagrams' ≈ *pictures* (4).
- 'icons' ≈ *symbols* (4).

Missing concepts in this context: *grouping diagrams*, and *hybrids* of the listed types (e.g. *chronological link diagram*, *statistical time chart*) (4).

**Peirce** (1885, 1886, 1902), distinguishes different types of signs:

- 'icon', subdivided by Peirce into:
  - 'image' ≈ a *literal* graphic object (3.1.1).
  - 'metaphor' ≈ a *metaphoric* graphic object (3.1.2).
  - 'diagram' ≈ a representation that involves *metaphoric* (3.1.1) *graphic relations*.
- 'index' seems to be related to *metonymic* correspondence (3.1.3), but is possibly not applicable to intentional graphic representation.
- 'symbol' ≈ an *arbitrary-conventional* graphic object (3.1.3).

**Richards** (1984, 2000, 2002) approaches graphic representations as consisting of 'significant elements' and their 'relational features':

- 'significant element'  $\approx$  *elementary graphic object* (2.3).
- 'relational feature'  $\approx$  *graphic relation* (2.1).

Missing concepts in this context: *composite graphic objects* (2.1), *nesting* (2.5.4) and the possible *recursive nature* (2.1) of syntactic structures.

Richards analyzes graphic representations with regard to three 'modes of interpretation':

- 'mode of depiction'  $\approx$  *mode of expression* (3.2).
- 'mode of organization'  $\approx$  *type of graphic relations* (2.1).
- 'mode of correspondence'  $\approx$  *type of correspondence* (3.1).

In Richards' approach, 'mode of depiction' and 'mode of correspondence' apply to 'significant elements', while 'mode of organization' applies to their 'relational features'.

Concerning possible **modes of depiction** for significant elements, Richards distinguishes:

- 'figurative'  $\approx$  *realistic picture* (3.2).
- 'semi-figurative'  $\approx$  *schematic picture* (3.2).
- 'non-figurative'  $\approx$  *abstract shape* (3.2).

Concerning possible **modes of organization** for relational features of significant elements, Richards distinguishes:

- 'variation'  $\approx$  *graphic relations* (2.1) that express *order* or *quantities* (3.4).
- 'linking'  $\approx$  *linking* (2.5.1). Linking expresses *concept-to-concept relationships* (3.4).
- 'grouping'  $\approx$  *graphic relations* (2.1) that express *categories* (3.4), e.g. relations of *spatial containment* (2.5.1).

Missing concept in this context: types of *metric spaces* (e.g. *integral* versus *composite metric spaces*, *graphic multiples*, *shared-axis multipanels*) (2.5.2, 2.5.4).

Concerning possible **modes of correspondence** for significant elements, Richards distinguishes:

- 'literal'  $\approx$  *literal* (3.1.1).
- 'semi-literal'  $\approx$  involving both 'literal' and 'non-literal' correspondence.
- 'non-literal'  $\approx$  *metaphoric* (3.1.2), *metonymic* (3.1.3), *rebus-based* (3.14) or *arbitrary-conventional* (3.1.5).

Missing concept in this context: application of type of correspondence to *graphic relations* (not only 'significant elements', but also the 'grouping, linking, or variation' that is achieved by their 'relational features', can be 'literal' or 'non-literal').

**Rogers** (1989) distinguishes four types of 'icons':

- 'resemblance icon'  $\approx$  *literal graphic object* (3.1.1).
- 'symbolic icon'  $\approx$  *metaphoric graphic object* (3.1.2).
- 'exemplar icon'  $\approx$  *metonymic graphic object* (3.1.3).
- 'arbitrary icon'  $\approx$  *arbitrary-conventional graphic object* (3.1.5).



**Strothotte and Strothotte** (1997) (and many other authors) distinguish between 'iconic' signs (which 'resemble what they stand for'), and 'symbolic' signs (such as 'geometric primitives, arrows, lines, and text labels'):

- 'iconic' sign  $\approx$  a *pictorial* (3.2), *literal* (3.1.1) graphic object.
- 'symbolic' sign  $\approx$  a *non-pictorial* (3.2), *arbitrary-conventional* (3.1.5) graphic object.

Missing concept in this context: *pictorial* graphic objects (3.2) that involve *other* than literal correspondences (3.1.2-3.1.5). The elephant for example that stands for the Republican Party - is it an 'iconic' sign or a 'symbolic' sign? See the discussion in section 3.2.

**Tufte** (1983, 1990, 1997) makes the distinction between 'data ink' and 'non-data ink':

- 'data ink'  $\approx$  the ink used for *information objects* (3.3).
- 'non-data ink'  $\approx$  the ink used for *reference objects* and *decorative objects* (3.3).

Tufte promotes 'layering and separation' and the use of 'small multiples':

- 'layering and separation'  $\approx$  the use of *visual levels* (2.2).
- 'small multiples'  $\approx$  *graphic multiple* (2.5.4).

**Tversky** (1995, 2001) approaches graphic representations as consisting of 'elements' and their 'spatial relations':

- 'elements'  $\approx$  *elementary graphic objects* (2.3).
- 'spatial relations'  $\approx$  *spatial relations* (2.5).

Concerning 'elements', Tversky lists 'general principles' of pictographs and symbols:

- 'straightforward' depictions  $\approx$  *literal* graphic objects (3.1.1).
- 'synecdoche' or 'metonymy'  $\approx$  *metonymic* graphic objects (3.1.3).
- 'rebus principle'  $\approx$  *rebus-based* graphic objects (3.1.4).
- 'schematic' icons  $\approx$  *schematic* graphic objects (3.2).
- 'conventionalized', 'arbitrary' depictions  $\approx$  *arbitrary-conventional* graphic objects (3.1.2).

Missing concept in this context: *metaphoric* graphic objects (3.1.2).

Concerning 'spatial relations', Tversky examines 'spatial metaphors':

- 'spatial metaphor'  $\approx$  *metaphoric* (3.1.1) *spatial relation* (2.5.1 and 2.5.2).

Missing concepts in this context: types of *metric spaces* (e.g. *integral* versus *composite metric spaces*, *graphic multiples*, *shared-axis multipanels*) (2.5.2 and 2.5.4), and, in general, *nesting* (2.5.4) and the possible *recursive nature* (2.1) of syntactic structures.

Twyman's (1979) 'schema for the study of graphic language' (1979) is a matrix that sets out two phenomena against each other:

- 'mode of symbolization'  $\approx$  *mode of expression* (3.2)
- 'method of configuration'  $\approx$  *syntactic structure* (2.5).

Concerning **mode of symbolization**, Twyman distinguishes:

- 'pictorial'  $\approx$  *pictorial* (3.2).
- 'schematic'  $\approx$  *abstract* (3.2).
- 'verbal/numerical'  $\approx$  *word* and/or *number* (3.2).
- 'pictorial and verbal/numerical'  $\approx$  *pictorial* combined with *word* and/or *number* (3.2).

Concerning **method of configuration**, Twyman distinguishes:

- 'pure linear'  $\approx$  *lineups* (2.5.1).
- 'linear interrupted'  $\approx$  *segmented lineups* (2.5.1).
- 'list'  $\approx$  Twyman's examples for this category include simple *vertical lineups*, *lineups of lineups*, and simple *tables* (2.5.1).
- 'linear branching'  $\approx$  *tree structures of linking* (2.5.1).
- 'matrix'  $\approx$  *tables* (2.5.1), *bar charts* (2.5.2), and metric spaces that are composed of two orthogonal *metric axes* (2.5.4).
- 'non-linear directed' and 'non-linear open'  $\approx$  *arbitrary spatial structures* (2.5) and *integral metric spaces* (2.5.2).

Missing concepts in this context: *containment* (2.5.1), types of *composite metric spaces* (e.g. *graphic multiples*, *shared-axis multipanels*) (2.5.4), and, in general, *nesting* (2.5.4) and the possible *recursive nature* (2.1) of syntactic structures.

Wilkinson (1999) uses some non-standard terms:

- 'aesthetic attributes'  $\approx$  *visual attributes* (2.4).
- 'guides'  $\approx$  *reference objects* (3.3).
- 'facets'  $\approx$  *graphic multiple* (2.5.4).

