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**The language of graphics**

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## CHAPTER 1

# Graphic Representation

“[...] as we embark on a visual information age.”

*MacEachren (1995, preface)*

Graphic representations seem to play an increasingly important role in our lives. Whether it is a cliché or not, modern life does appear to be characterized by an ever growing access to *information*. While our common sources of information (e.g. books, newspapers) used to be mainly textual, we are now seeing more and more information presented through diagrams, pictograms, maps and charts. We see such graphic representations on paper as well as on signage and on screen. Some types of graphic representations have developed due to recent advances in computer technology, others were invented in the eighteenth century, and some can already be found on archeological objects from ancient cultures.

Various collections of beautiful graphics have been published (e.g. Tufte 1983, 1990, 1997), and several authors have discussed the cognitive advantages of graphic representations over textual representations (e.g. Wright and Reid 1973, Card et al. 1999 on pp. 15-17, Tversky 2001). However, we still know little about, for example, the internal structure of graphics. Is there a set of general compositional principles that all graphics depend on? Does the ‘visual language’ of graphics involve something like a ‘grammar’? Because of the increasing use of graphic representations, it is both interesting and relevant to find out more about how they work as representations of

information. This chapter offers a brief introduction to the subject of graphic representations and their 'visual language', and then provides a description of the aims of this thesis.

What exactly is a 'graphic representation'? Examples of what we would like to regard as graphic representations here include ancient maps and Egyptian hieroglyphs, but also family tree diagrams, pictorial statistical charts, and modern 3-D computer visualizations. In need of some kind of definition, we will work with the following:

**A graphic representation is**

a visible artifact on a more or less flat surface,  
that was created in order to express information.

The first aspect of this definition concerns the fact that a graphic representation is something visual, and that it is usually found on a more or less flat surface, for example on paper, on a wall, or on screen. In this sense graphic representations live in 'flatland', a term used by Edward Tufte in his remark that "the world portrayed on our information displays is caught up in the two-dimensionality of the endless flatlands of paper and video screen." (Tufte 1990, p. 12). Indeed, a physical, real-world model of a molecule for example would usually *not* be regarded as a graphic representation, while a drawing of it *would* be regarded as a graphic representation. Many graphic representations do show three-dimensional spaces and objects, so while the *medium of display* of a graphic representation is usually flat, *what is displayed* may certainly be three-dimensional in character. A discussion of this issue is in section 2.2.

The second aspect of our definition concerns the fact that a graphic representation is purposefully created with the goal to express information. This means that self-occurring, 'natural signs' such as footprints in the sand, are not regarded as graphic representations. Incidentally, a schematic map that is scratched into the sand with a stick, *does* qualify as a graphic representation. Note that while the term 'graphic' makes most people think of colorful stuff on paper or on a computer screen, our definition above says nothing about the medium in which the visible artifact is created.

How about the goal of expressing information? Many visible artifacts on flat surfaces are indeed created with some goal regarding the viewer. The main goal may, however, *not* be only to express *information*. Concerning graphic design, Richards makes a distinction between "the intention to amuse, delight, persuade, invigorate, provoke or otherwise stimulate" and the "intention to describe, explain, inform or instruct" (Richards 1984, p. 0/8). Of course these two categories are not mutually exclusive. In the spirit of our definition, visible artifacts involving mainly Richards' second category of intentions would be referred to as graphic representations, while those involving mainly Richards' first category of intentions might not. The

chosen focus here means that this thesis will not concentrate on images in advertising, nor will it contemplate art.

Complex computer visualizations that display large amounts of data are graphic representations. So are the red dot and the blue dot on my shower faucets. According to our definition, a *photograph* may also serve as a graphic representation, especially if it is augmented with explanatory labels. Note in particular that with our definition of graphic representations we choose to include *written text* - regardless of whether it is written with pictorial hieroglyphs or with the letters of the Latin alphabet (e.g. the text you are reading now). Written text as a special case of graphic representation is discussed in section 3.2. Chapter 4 is devoted to the *classification* of graphic representations.

Having characterized what we will regard as graphic representations, we will now briefly explore the notion of the 'visual language' of such representations (section 1.1), and then discuss the aims of this thesis (section 1.2).

## 1.1 Visual Language

A graphic representation can be regarded as an expression of a **visual language**, and can be analyzed with regard to its **graphic syntax** and with regard to its **interpretation**. Chapter 2 of this thesis is devoted to examining the notion of *graphic syntax*, and Chapter 3 is devoted to issues related to the *interpretation* of graphic representations.

In the literature different attempts can be found to approach graphic representations with notions from the study of language, for example in Clive Richards' 'Diagrammatics', and Robert Horn's 'Visual language'. The proposals of these (and other) authors are examined and criticized throughout this thesis.

Is there *one* visual language of graphic representations, or are there *many different* visual languages? The notion of *many different* visual languages seems appropriate, allowing us to distinguish for example 'traffic-sign-languages' from 'subway-map-languages', 'quantitative-bar-chart-languages' and 'color-coded-geographic-surface-languages'. In this context a possible alternative term for 'language' is the term 'schema', such as in 'traffic-sign-schemas', 'subway-map-schemas', 'quantitative-bar-chart-schemas' and 'color-coded-geographic-surface-schemas'. Specific visual languages (schemas) can be thought of as having their own set of compositional rules and their own set of categories of graphic constituents with specific syntactic roles. Compositional rules and syntactic roles are notions of *graphic syntax*, and are discussed in Chapter 2. Sometimes legends and annotated axes help to define the specific visual language of the representation that they are part of (see the discussion of *reference objects* in section 3.3). In this sense a graphic representation may use its individual, very specific visual language. This means that designing a graphic representation of information does not only involve a *translation* of that information into a visual language, but it often also involves the very *creation* of that specific visual language (Engelhardt et al. 1996, p. 2).

In spite of the multitude of possible visual languages, these languages seem to have many general principles in common. A specific visual language can be regarded as involving a *subset* of these general principles of visual languages. Exploring such *general principles of visual languages* is the aim of this thesis. In the next section I will clarify the specific aims of the thesis in more detail.

## 1.2 Aims of this Thesis

Some authors comment on what they think *could* be written on the 'language' of graphics, but has *not* been written yet. For example:

"The principles for a grammar of graphic presentation are so simple that a remarkably small number of rules would be sufficient to give a universal language."

*Brinton (1914, p. 3)*

And, seventy-five years later:

"Unlike verbal language, in which there are a set of syntactic and semantic rules which provide us with a means of disambiguating the meaning of verbal language, pictorial language has, as yet, no equivalent set of rules [...]"

*Rogers (1989 p. 106)*

### DECONSTRUCTING GRAPHICS

While there are authors who are very optimistic, others are very pessimistic about any search for systematic accounts of meaning in graphic representations. Critics inspired by Wittgenstein's notion of language games, and by postmodernist and deconstructionist ideas, have judged such endeavors to be naïve and even futile. For a brief discussion of relevant postmodernist views see MacEachren (1995, pp. 10-11). I completely agree with views of meaning as being a social construct, of meaning being neither fixed nor absolute, and of all interpretation being context- and culture-dependent. I agree that rhetorical and connotational aspects play an important role in many graphic representations. These insights, however, are *not in contradiction* with the notion that meaning in graphics involves phenomena with various systematic tendencies. Regardless of the degree to which such systematic tendencies or systematic principles may be driven by culture and context, they *do* seem to play important roles in the creation and interpretation of graphics. In summary, I believe that adopting the notion of 'meaning as a social construct' does not necessarily entail that one has to deny the role of systematic principles in graphic representations. It appears to be a useful endeavor to seek to understand such systematic principles in graphic representations. This thesis is devoted to that endeavor.

Compared to the postmodernist skepticism, the views of other authors go to the opposite extreme:

"The principles of information design are universal - like mathematics - and are not tied to unique features of a particular language or culture." *Tufte (1990, p. 10)*

"Graphics is a tool that obeys universal laws that are unavoidable and undisputable". *Bertin (2000/2001, p. 5)*

The framework proposed in this thesis is concerned with such possible 'universal' principles of graphic representation. These principles are claimed to be *universal* in the sense that they seem to extend across cultures and across the broad spectrum of different types of graphic representations. In this thesis I will *not* discuss culture-specific visual symbology, such as culture-specific meanings of colors, or culture-specific meanings of pictorial symbols. Such issues concern *specific visual vocabularies*. Instead, I will concentrate on *general principles of visual languages*.

But what does the framework proposed here add to the various frameworks that can be found in the literature? Well, there are three main aspects that distinguish the framework proposed here from existing frameworks. This thesis proposes a *comprehensive* and *unifying* framework for analyzing the visual language of graphic representations in general, and for analyzing their *graphic syntax* in particular. In the following paragraphs I will briefly elaborate on what it is that makes this framework *syntactic*, *comprehensive*, and *unifying*.

## A SYNTACTIC FRAMEWORK

I mentioned in section 1.1 that several attempts can be found in the literature to approach graphic representations with syntax-related notions. Such attempts include Michael Twyman's 'Schema for the study of graphic language' (1979), Clive Richards' 'Diagrammatics' (1984), Robert Horn's 'Visual language' (1998) and Card, Mackinlay and Shneiderman's approach to 'Visual structures' (1999). The merits and shortcomings of these approaches are examined at the appropriate points throughout the course of the thesis.

One of the main aspects that are missing in the existing approaches is *recursiveness* of the syntactic analysis. However, a recursive nesting of syntactic (de-)composition rules in the sense of Noam Chomsky's generative grammars seems to be what is needed for the analysis of graphic structures. In this thesis we propose such an approach (described in section 2.1). Note that an exception to the lack of recursiveness in existing syntactic approaches is Lakin's (1987) work, which is discussed at the end of section 2.1.

A second main aspect that is missing in the existing approaches is a *broad inventory* of syntactic principles that are involved in graphic representations, which would enable the syntactic analysis of the structure of any randomly chosen graphic representation. The existing approaches seem to describe only subsets of these syntactic principles. In general, the use of visual attributes such as size, shape, and color is well studied, while the role of spatial structure has received much less attention (concerning spatial structure think for example of phenomena such as superimposition, labeling, multiple charts aligned along a shared axis, etc.). In this thesis we claim to offer such a broad inventory of syntactic principles (in section 2.5).

A third main aspect that is missing in the existing approaches is a description of the different *syntactic roles* that graphic objects may play within a graphic representation (e.g. a graphic object may serve as a *surface locator in a metric space*, or as a *label* for another graphic object, or as a *connector* between two other graphic objects, etc.). In this thesis we examine these different syntactic roles (see subsection 2.5.3).

In summary, no detailed and broadly applicable framework has been developed yet concerning the recursive syntactic principles in graphic representations. Proposing such a universal grammatical framework for understanding graphic representations is one of the main aims of this thesis. Chapter 2, titled 'Graphic syntax', is devoted to this aim. Our general approach to graphic syntax is based on the principle that syntactic structure parallels semantic structure - see our remarks about compositionality of meaning in section 2.1.

## A COMPREHENSIVE FRAMEWORK

Most of the existing literature on graphic representation covers only specific aspects of graphics (e.g. structural aspects, semiotic aspects, classification), or it covers only certain types of graphics, such as maps (e.g. MacEachren 1995), pictograms (Horton 1994), or statistical graphics (e.g. Card et al. 1999, Wilkinson 1999). In contrast, the approach proposed here is claimed to be 'comprehensive' in the sense that:

- it integrates *various different aspects* of graphic representations into *one coherent framework*. For example,
  - *structural aspects (graphic syntax)* are discussed in Chapter 2,
  - *semiotic aspects (type of correspondence)* are discussed and related to structural aspects in section 3.1,
  - *classifications* of graphic representations are discussed and related to structural and semiotic aspects in Chapter 4.
- it can be applied to the *complete spectrum of graphic representations*, from maps to bar charts, from pictorial illustrations to written text, and from single pictograms to complex multipanel computer visualizations. Specific visual languages (e.g. 'the language of traffic signs', 'the language of

color-coded vegetation maps', 'the language of Venn diagrams') can be thought of as having their own set of composition rules, and their own set of categories of graphic constituents with specific syntactic roles. In the existing literature no general notion of graphic syntax has been proposed that would be able to account for the broad spectrum of graphic structures that are generated by these various visual languages.

The forty 'boxed' example figures that are contained in this thesis serve to illustrate the broad range of graphic representations to which the proposed framework can be applied. In addition to a brief syntactic analysis (according to Chapter 2), the caption of each example figure includes an assessment of the type(s) of correspondence that are involved in the figure (according to section 3.1), and a general classification of the figure (according to Chapter 4).

As a side remark, note that the essence of the proposed framework does not lie in the choice of *terms* - all terms used in this framework could be exchanged for alternative terms - but in the existence and interaction of the *phenomena* that are referred to by these terms.

The existing work that comes closest to having the same aims as this thesis is Richards' 'Diagrammatics' (1984). Richards offers a quite comprehensive approach and a (very basic) analysis of syntactic principles ('grouping, linking, and variation'), although he is not concerned with discussing or 'unifying' existing graphic theories (see below). Richards' work is discussed and sometimes criticized throughout this thesis.

## A UNIFYING FRAMEWORK

Several approaches can be found in the literature that explicitly state as their goal to offer a terminology for discussing graphic representations (e.g. Tufte 1983, pp. 10, 15; Richards 1984, pp. 1/4, 10/1). However, no author so far has offered an analysis of how the proposed vocabulary relates to the already existing jungle of terminology for discussing graphics, proposed by other authors. Nobody has mapped out how the various proposed terminologies could be related to each other. Doing exactly that is another aim of this thesis.

One of the reasons for the confusing diversity of terminology for discussing graphic representations is that the literature comes from a wide variety of different disciplines - from graphic design to statistics, and from computer visualization to semiotics. Twyman (1979) has commented on the lack of integration between the disciplines that are concerned with graphic representation:

"Those who study letter forms [...] are likely to be practising typographers or historians of printing; those who

study the iconography of paintings are likely to be art historians. Though related to one another in that both are concerned with forms of graphic language, the two disciplines hardly interact. To a large degree the same must be said of other fields of scholarship concerned with graphic language within a theoretical framework, such as semiology, psychology, topology, anthropology, palaeography, linguistic science, and cartography."

*Twyman (1979, p. 119)*

An impressive inventory of concepts from different disciplines has been accomplished by Alan MacEachren with his book 'How maps work'. However, while MacEachren discusses a broad range of issues relating to graphic representation, his work is basically restricted to the field of cartography, and does not examine issues such as the possible uses of spatial arrangement for representing non-geographical information.

In this thesis an attempt is made to integrate all relevant approaches and concepts from the literature into one consistent framework that can serve as a 'unified theory of graphic representation'. Throughout the thesis the detailed distinctions made by the relevant authors are thoroughly analyzed and compared with each other in terms of the proposed unifying framework. 'Theory comparison tables' are included in various sections to provide overviews and matchings of terminologies. Finally, section 5.2 offers terminology translations, arranged per graphic theory.

#### NOT A NORMATIVE FRAMEWORK

An aspect of graphic representations that falls *outside* the aims of this thesis is the prescription of 'rules of good design'. Like academic work in linguistics, the work presented here is *descriptive* in the sense that it examines occurring phenomena, rather than *prescriptive* in the sense of postulating rules of 'correctness'. Studies like the one presented here may however help to provide the concepts and the terminology that are necessary for discussing the phenomena that are involved in good and bad design.

#### STATIC VERSUS DYNAMIC AND INTERACTIVE GRAPHICS

We are limiting our current analysis to *static* graphic representations. In the light of the numerous existing research projects on *dynamic* and *interactive* visualization, our chosen scope may at first glance seem surprising (for seminal publications in the area of automatic and interactive visualization see for example Mackinlay 1986 and Card et al. 1999). Note that, despite the fascinating developments of electronic media, the amount of *static* diagrams, charts and infographics that is being published in books, magazines and

newspapers has only been growing. Explaining something through a good graphic representation, in a textbook for example, is usually an exciting and worthwhile challenge, even if you can not click on it. Of course, analyzing the visual language of dynamic and interactive graphic representations will be a logical following step. Most concepts that are discussed in this thesis *do* apply to dynamic and interactive graphic representations. However, animation and interaction involve various additional aspects that are not accounted for here. In the context of this thesis we decided to take one step at a time: We will first try to understand static versions of graphic representations, before we will try to understand dynamic and interactive versions.

Having stated the major aims of this thesis, we will begin with an analysis of *graphic syntax* (Chapter 2), followed by an analysis of the *interpretation* of graphic representations (Chapter 3). We will then briefly discuss *classifications* of graphic representations (Chapter 4), and finally *apply* the framework developed here to the analysis of graphic representations and to the analysis of existing graphic theories (Chapter 5).