# Retinal Coding and Mapping

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# Contents

**Abstract**

Nearly 30 years ago Jacques Bertin's book "Semiology of Graphics" was published which is now seen as a standard work in the field of information design. In it he breaks down information design to basic principles and in one chapter thoroughly describes retinal variables.

Retinal variables are visual features which can depict information in a way that its meaning is clear at a glance, without a concios effort of making sense of the data. A typical field of application is the visualization of (additional) information on a map.

We researched work on retinal variables, its physiopsychological background and its applications. We found well researched and new aspects such as "retinal" variables for other senses and applications. Modern technological development has also influenced the application.

# Chapter 1

# Introduction

The French cartographer Jacques Bertin did essential work in the field of graphical representation of information. Even though his creative period was settled before the rising age of information technology, almost no recent work on information visualization gets along without at least one of his essetial publications.
In his book [Bertin, 1983] he introduces “Retinal Variables” as a third component in visualizations after two planar dimensions.
In this survey we present about Bertin’s work, followers, perceptive basics, different approaches and impacts and application of investigation on retinal variables.

## 1.1 Retinal Variables

The eye’s retina is sensetive to graphical properties independent of their position. These properties were called “retinal variables” by Bertin [1983]. A designer can relate to component of a visualization with one of these variables:

- **Size**
- **Value**
- **Texture**
- **Colour hue**
- **Orientation**
- **Shape**

Any of these variables can be used in the representation of any component - or, the other way around - data attributes can be mapped to these properties in a visualization. But not each variable is suited to every component [Bertin, 1983].
We try to give an overview of scientific research on analysing and using these retinal properties in visualizations.

## 1.2 Outline of this Document

We start with an overview of Bertin’s work on rentinal encoding. Although his analysis might not be complete and unfailing, it gives the reader an idea what we are dealing with. Further research often refers to Bertin [1983]. This chapter does not contain anything about arizing possibilities due to computerized information processing.

In Chapter 3 we introduce followers who rounded and extended Bertin's work. While Bertin set up his insights on theoretical analysis and his experience as a graphics designer, investigation based on perceptual user experiments is presented. Aspects of modern information processing are introduced. Guidelines helping us to present information in a right way are brought up.

Chapter 4 demonstrates some aspects of retinal variables in human perception in a physiophsycological way, helping us to understand why things work like they work.

Later, in Chapter 5, we step up some levels of absraction and show how created knowledge is applied in syntheses of information visualization. Frameworks and taxonomies for automatic and assisted generation of computer graphics are lined out.

Chapter 6 deals with influences of retinal encoding in Computer Interfaces, with a focus on temporal resolution and the aspect of interactivity. New aspects due to mobile devices are marked.

Finally we sum up our conclusions and insights.

# Chapter 2

# Basic Research: Bertins Approach

Bertin Bertin [1983] provided the first systematic treatment of visual encodings [Heer et al., 2009]. In this chapter the thoughts of the book's section on retinal variables are summerized, structure and terms are borrowed.

## 2.1 Visual Variables

Due to Bertin's analysis, a graphics designer placing marks in a plane has eight visual variables to work with. Two of them represent the planar dimensions, further he recognizes six others, independet of spacial alignment:

- **Size**
- **Value**
- **Texture**
- **Colour hue**
- **Orientation**
- **Shape**

To recognize variations of a mark's spacial alignment, "muscular" eye movement is necessary, whereas variation recognition of the listed properties are only done by the retina. Therefore, Bertin introduces the term *retinal variables*.

At the level of information visualization, the two planar dimensions are able to represent two components of the information, in (geographic) maps they these components are the space. To introduce a third component of information, the usage of the retinal variables is necessary.

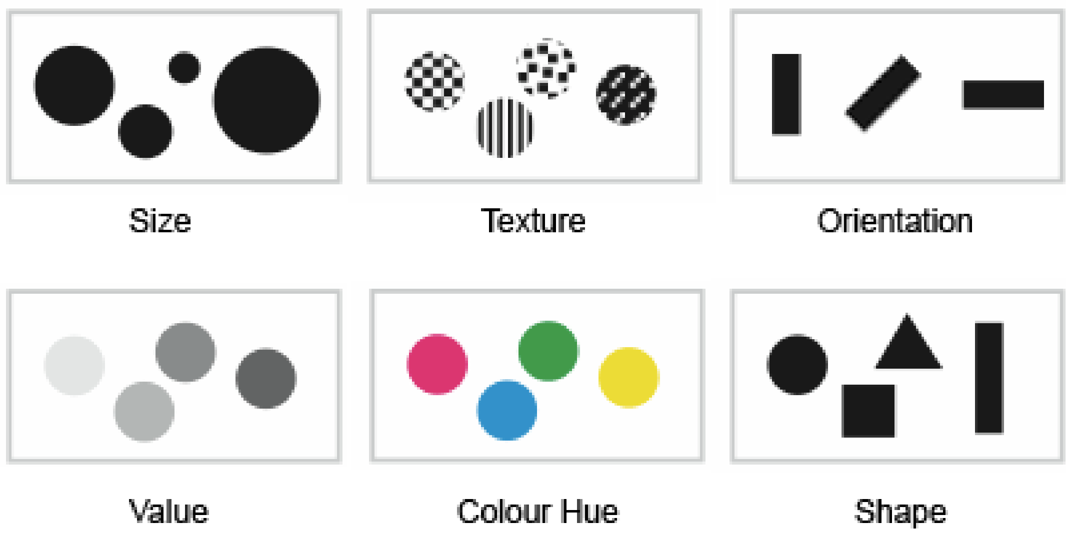



**Figure 2.1:** Retinal variables defined in Bertin [1983].
Apart from their planar position objects can vary in size, value, texture, colour hue, orientation and shape.

## 2.2 Level of Organization of Retinal Variables

Bertin raises a perceptual classification which he calles *the level of organization of retinal variables*.
He distinguishes between four attributes:

- **Associative perception**
- **Selective perception**
- **Ordered perception**
- **Quantitative perception**

Bertin gives examples for all of these and assignes the classes to the different variables or not. For each class, he provides a test to verify his assignments.

### 2.2.1 Associative Perception

Associative perception is useful when one is seeking to equalize a variation, and to group correspondences with all categories of this variation combined [Bertin, 1983].
As an example he mentions a map where a sign represents 500 inhabitants, but signs differ in the inhabitants' class (farmers, herdsmen, normads). All signs together should represent the total number of inhabitants, independent of their class. Coding has to be done with a associative variable.
Bertin classifies shape, orientation, colour and texture as associative, whereas value and size are dissociative.

As a proof, he puts signs with different variations in a square, with associative variables the human visual system can immedeatly reconstruct a uniform area, with dissociative it cannot (compare Figure 2.2).

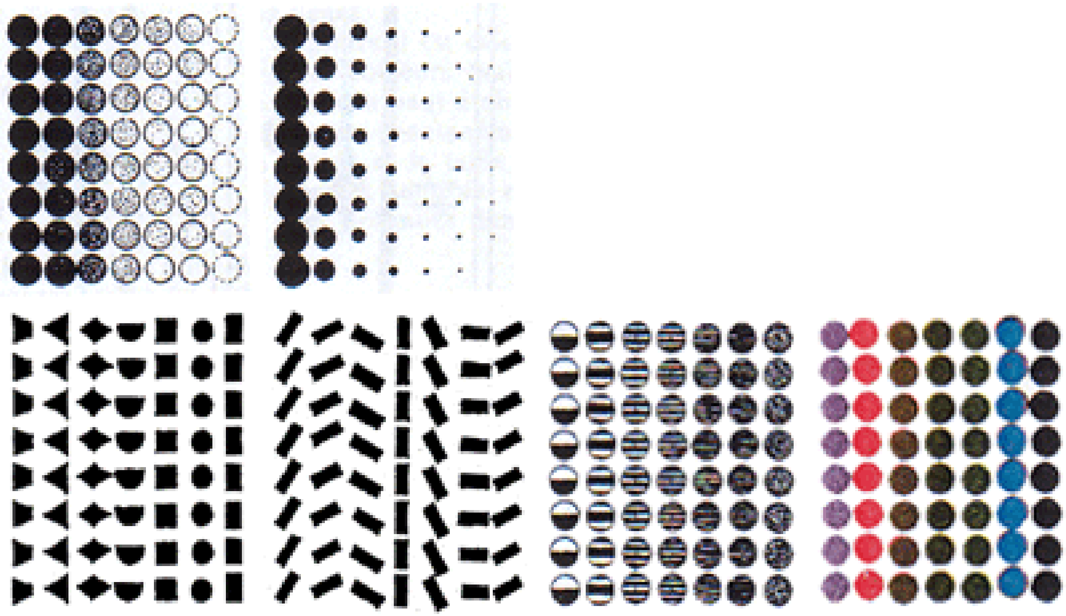


**Figure 2.2:** Test for association perception from Bertin [1983].
Top: variables *value* and *size*, the elements in the squares do not form a uniform area.
Bottom: variables *shape*, *orientation*, *texture* and *color* immedeatly form a uniform area.
shape.

### 2.2.2 Selective Perception

Selective perception is used to give an answer to the question: "Where is a given category". The eye must be able to isolate all the elements of this category immedeatly.

The provided test should demonstrate that shape is not selective at all, nor orientation when represented by area (compare Figure 2.3 and Figure 2.4).

### 2.2.3 Ordered Perception

When comparing two or several orders, ordered perception must be used. Again, comparison can be imedeatly. Due to Bertin a variable has ordered perception when consulting a visualization's legend is not necessary to see an order relation.

Shapes, orientations and colors are not ordered, value, size and texture should be (compare Figure 2.3 and Figure 2.4).

### 2.2.4 Quantitative Perception

According to Bertin [1983], quantitative perception is given when both

- we seek to define numerically the ration between two signs and
- we seek to group homogenous signes.

As a test, again we try to immeadiatly find out the ratio between two signs, without consulting the legend.
*Size* seems to be the only variation that is quantitative.

Value variation is not quantitative, because according to Bertin white cannot serve as a unit for measuring grey and grey cannot for black (compare Figure 2.4).

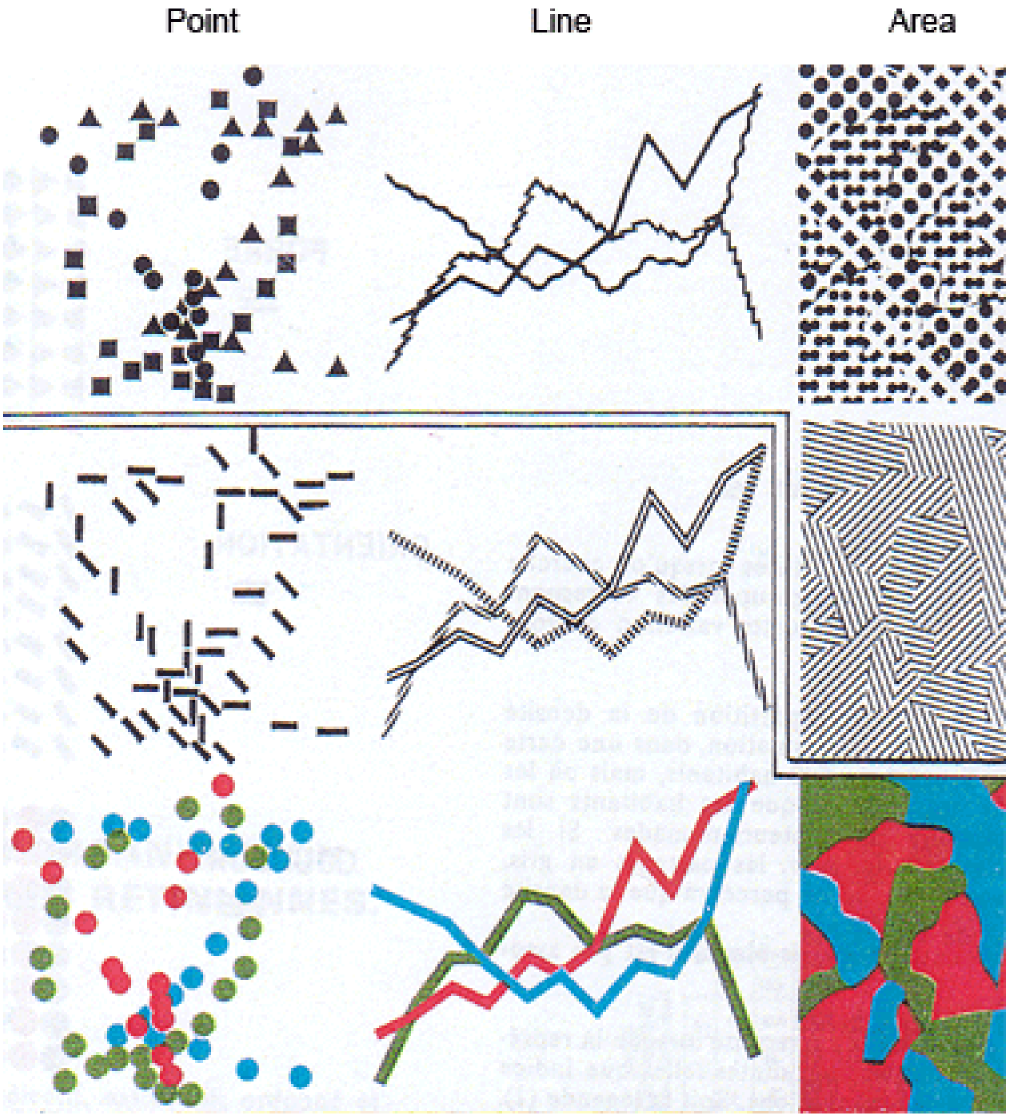



**Figure 2.3:** Test for *selective*, *ordered* and *quantitative* perception from Bertin [1983] - Part 1
(original test visualization from the book was split into 2 parts)
Variables (top to bottom): *shape*, *orientation* and *colour hue*.

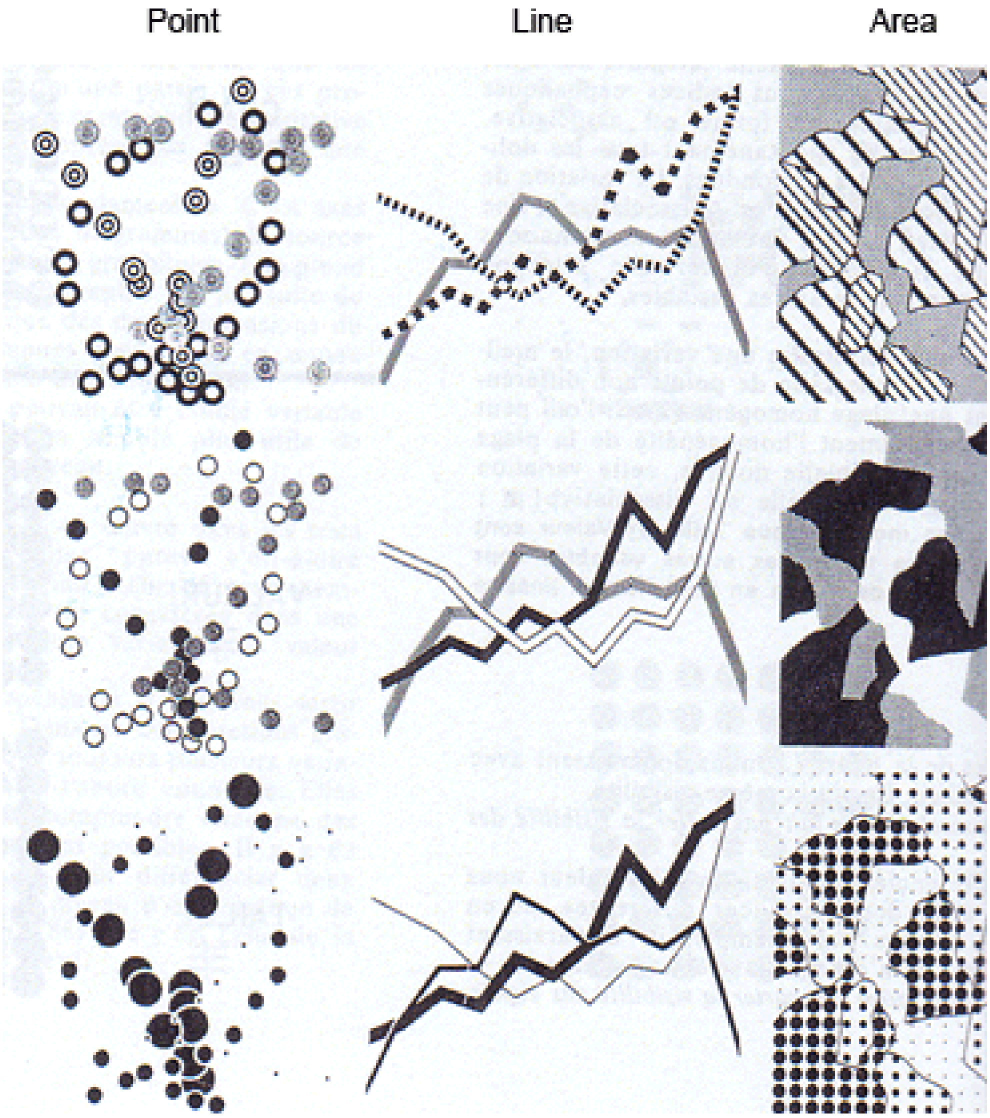



**Figure 2.4:** Test for *selective*, *ordered* and *quantitative* perception from Bertin [1983] - Part 2 (original test visualization was split into 2 parts)
Variables (top to bottom): *texture*, *value* and *size*.

### 2.2.5 Summary - Conclusions

In the end, Bertin counts the number of attributes each variable has. The planar dimensions are able to represent every type of the defined relations. In contrast, none of the retinal variables has all of the attributes. Bertin reasons that there are higher variables, processing a bigger number of properties, and lower ones, processing a smaller number. He defines the following hierarchy: planar dimensions - size - value - texture - color - orientation - shape.

He summerizes the level of the variables with all their properties in a table of properties of the retinal variables (Figure 2.5).

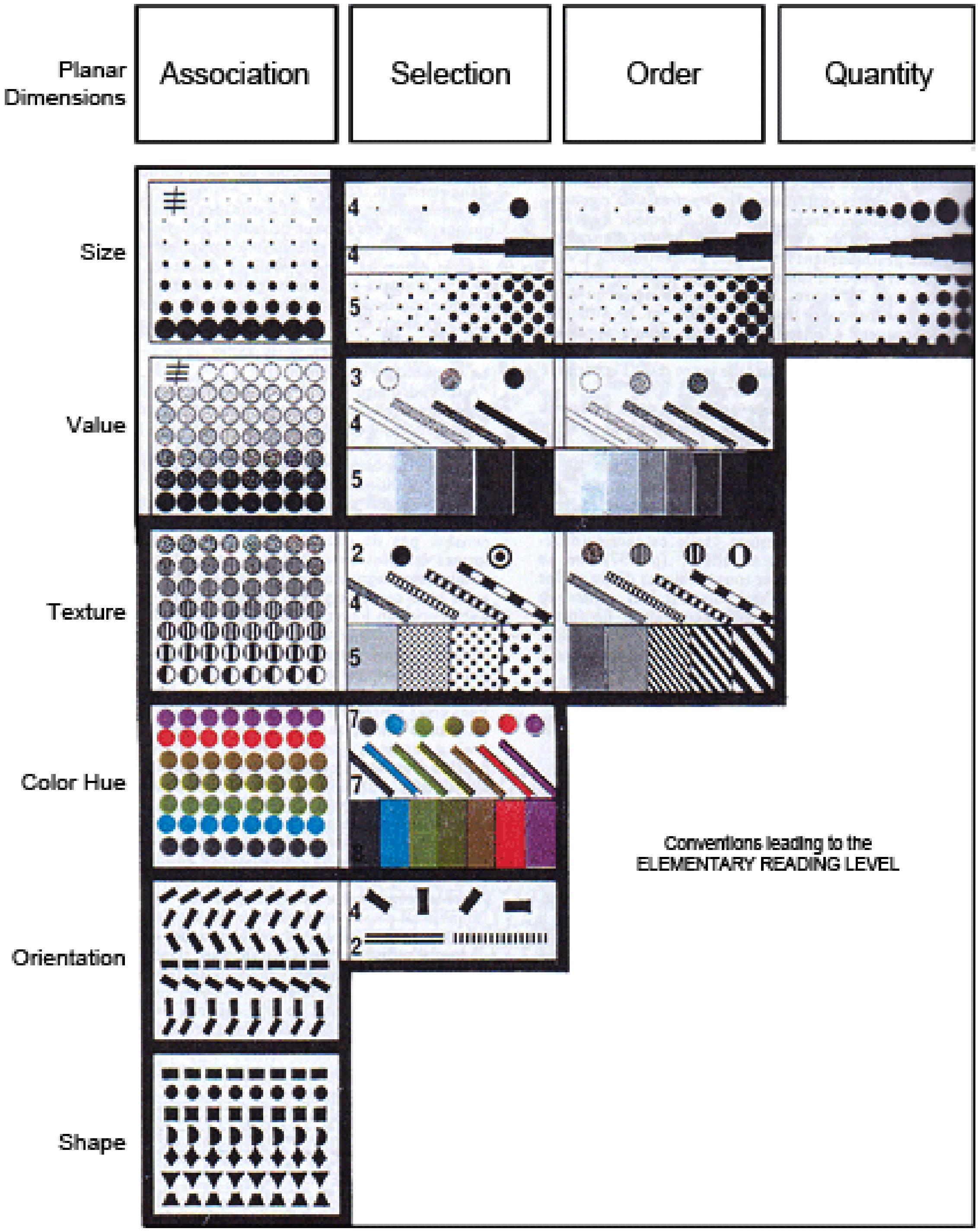



**Figure 2.5:** Bertins Table of Properties of the Retinal Variables [Bertin, 1983].

# Chapter 3

# Evaluation of Variable Usage and Derived Guidelines

This chapter deals with systematic qualification attempts of retinal variable usage. The usefulness of encodings often requires user testing Card et al. [1999], hence we will also give an overview how perceptual experiments with human subjects have been done.

## 3.1 First User Experiments and Their Results

### 3.1.1 Methodology, Results and Impacts

Jacques Bertin's work based on his experience as a graphics designer, but not on perceptual experiments invoking test users.
Cleveland and McGill [1985] started perceptual exeriments with human subject to place rankins of visual variables displaying quantitative data on “more rigorous scientific footing”. Subjects were shown two marks in a chart each representing the same dimension. They were asked to estimate the percentage the smaller value was of the larger [Heer et al., 2009]. Rankings about the relative effectiveness of visual variable were then derived on estimation accuracy. Their results are presented in Table 3.1.

Cleveland and McGill's methodology was reused adopted for a series of experiments up to the present.[Heer et al., 2009]

Quite recently, Wigdor et al. [2007] went for a rerunning the experiments for analysing visual variable behavior in table-top and multi-display environments.

| Rank | Aspect judged |
|---|---|
| 1 | Position along a common scale |
| 2 | Position on identical but nonalligned scales |
| 3 | Length |
| 4 | Angle Slope |
| 5 | Area |
| 6 | Volume Density Colour Saturation |
| 7 | Volume Colour hue |

**Table 3.1:** Perceptional effectiveness ranking for quantitative data due to Cleveland and McGill [1985]

### 3.1.2 Differences to Bertin's definitions

#### Classification

While Bertin [1983] analysed four classification types for information, this experiment just considered the quantitative aspect.

#### Variable types

As we can see in the results, Cleveland and McGill [1985] used variables different to Bertin's ones for their tests.
Generally, Card et al. [1999] argue that Bertin's definition of six retinal variables is a good basic set for their purpose, but incomplete. They mention that there are various other possibilities to keep in mind, crispness, resolution or transparency to name just a few of them.

## 3.2 Further work

Mackinlay [1988] extended the properties tested by Cleveland and McGill [1985] according to different types of information, i.e. quantitative, ordinal and nominal information within a theory approach, but did not experimentally verify these modified rankings (see 3.1). Compared to Bertin's classification, the assocative perception is missing in Mackinlays analysis and all further work.
All in all, he mapped Bertin's classification upon the variable types used for the perception experiments described.

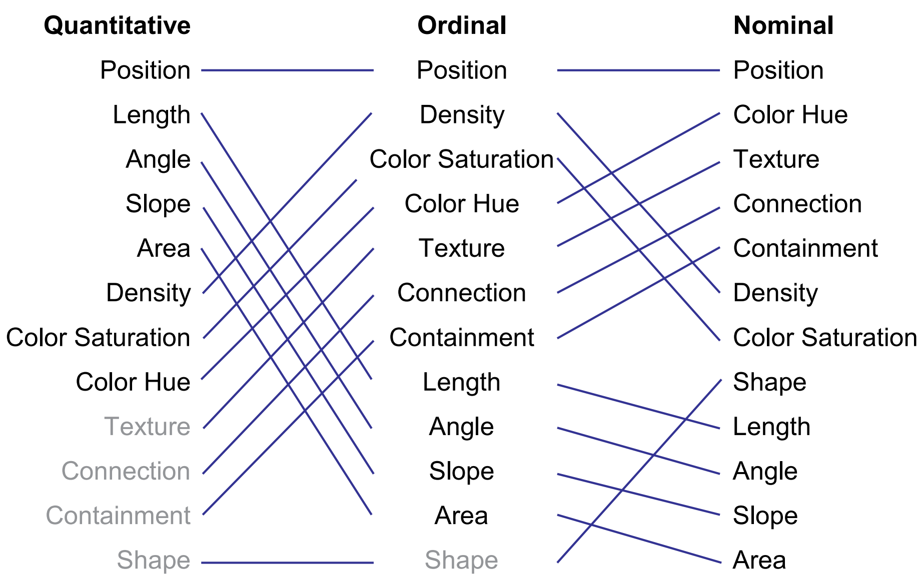



**Figure 3.1:** Ranking of perceptual tasks according to Mackinlay [1988].
The columns represent three different types of information. Tasks higher in the chart are perceived more accurately than lower tasks in the chart. The tasks shown in gray are not relevant to that type of information.

McEachren [1995] provided a more detailed ranking by classifying suitability of Bertin's variables for each of Mackinlays information types in a 3-level scale (good, marginally effective, bad). His results were later widespread by Card et al. [1999], summed up in Figure 3.2. This could be considered as a modified version of Bertin's *Table of Properties of Retinal Variables*. The main difference are that Bertin assignments are only boolean and therefore stricter.

Bertin claims that visual variables have certrain perceptual properties or not, the latter models try to compare the relative effectiveness of a variable expressing a certrain relation.
To give an example, Bertin asserts that *colour* cannot communicate an order relation to the observer without leading her or him to the “elementary reading level”. Figure 3.2 suggests that *colour* is just bad in communicating order relations compared to *grayscale* or *size*.

| | Spacial | Q | O | N | Object | Q | O | N |
|---|---|---|---|---|---|---|---|---|
| Extent | (Position) | ● | ● | ● | Greyscale | ◐ | ● | ○ |
| | Size | ● | ● | ● | | | | |
| Differential | Orientation | ◐ | ◐ | ● | Colour | ◐ | ◐ | ● |
| | | | | | Texture | ◐ | ◐ | ● |
| | | | | | Shape | ○ | ○ | ● |

**Figure 3.2:** Relative effectiveness of different retinal properties. Data based on McEachren [1995].
Q = Quantitative data, O = Ordinal data, N = Nominal data.
Filled circle indicates the property is good for that type of data. Halffilled circle indicates the property is marginally effective, and open circle indicates it is poor [Card et al., 1999].
The values are serperated into spatial properties and object properties according to which area of the brain they are believed to be processed [Kosslyn, 1994].

## 3.3 Perceptual tasks and user experiments

Card et al. [1999] state that usefulness of certrain variables requires testing. Kosara et al. [2003] give a good overview why, how and when we should conduct user studies within visualization problems and conclude that user experiments can bring excellent results in low-level vision tasks. Therefore, user testing is a powerful tool to verify or enhance retinal variable usage in guidelines of in a particular visualization.

While most of the experiments that are done are based on measuring time and error rates in a task, Huang et al. [2008] present about a different approach. They additionally try to consider the user’s congitive load when performing a visual task.

# Chapter 4

# Perception

This chapter mostly discusses graphical perception as this is one of the basics in information visualization and its applications. Later on we try to expand beyond graphical perception and discuss other features such as auditory or haptic features.

## 4.1 Introduction

Graphical perception is the visual decoding of various information in e.g. graphics done by the visual system of humans. It is very useful respectively essential to know at least about the basics of human perception. Implementing visualization systems the right way can offload the task of encoding data and information, or at least a big portion of it, to the human visual system - implemented bad or wrong the whole decoding process might fail – and so does the whole visualization [Cleveland and McGill, 1985].
So there is need of perceptually motivated methods in visualization. The simplest approach is to incorporate facts that are already known from perception research literature. Unfortunately, as results in perception research are generally obtained by methods that do not adequately reflect visualization practices, it is often doubtful whether they are also valid in visualization applications. So Kosara et al. [2003] stated that Experiments and user studies are needed, to verify results from perception research in more visualization-realistic contexts.
Since this is often a very time-and energy-consuming process, an important question is whether the benefits from such experiments outweigh the costs. [Berg et al., 2008]

## 4.2 Color

Neural signals from the rods and cones in the retina (see Figures 4.1 4.2) are transformed by neural connections in the visual cortex into three opponent color channels:

- luminance channel black-white
- chromatic channel red-green
- chromatic channel yellow-blue

The luminance channel enables to see form, shape and detailed patterns (to a greater extend than the other two channels).
The information derived from the two chromatic channels is more of categorical nature. Colors get categorized in fields like ”red”, ”green”, ”yellow” and so on. Hues such as turquoise or lime green are seen more ambiguously.
Another relevant theoretical point is that simultaneous contrast (perceived color is affected by surrounding colors) occurs in all three opponent channels. This can lead to huge errors when interpreting color-based values. [Kosara et al., 2003]

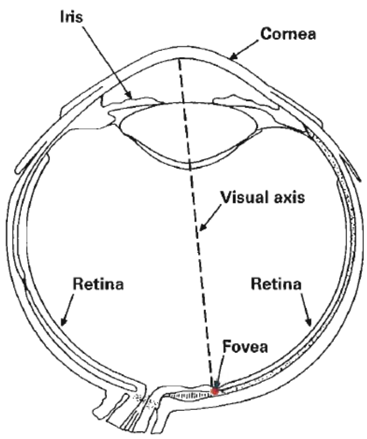



**Figure 4.1:** The human eye [Card et al., 1999]

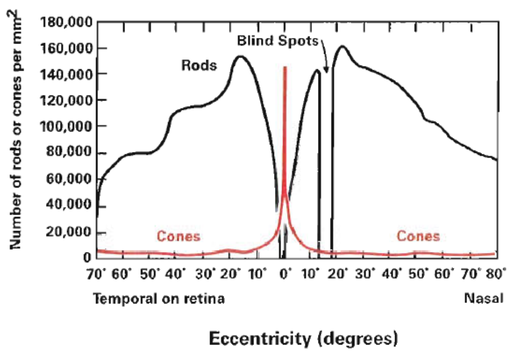



**Figure 4.2:** Distribution of these photoreceptors is nonuniform. In a central area, called the fovea, cones are dense. In outlying areas, rods with larger receptive fields predominate. [Card et al., 1999]

## 4.3 Spacial

The brain utilizes low-level visual attributes for performing complex visual tasks such as the perception of shape, Gestalt, and depth which are referred to as spatial vision [Ferwerda, 1998]. Other higher order tasks are figure-ground perception and texture perception. The involved visual attributes are called high-level visual attributes [Wünsche, 2004].
Texture is perceptually characterized by its spatial frequency, contrast and orientation [Schiffman, 1996].
Recognition of feature patterns is accomplished using primitive textural features (textons) such as length, width and orientation with line segment orientation being particularly important. Pattern detection is orientation dependent and is influenced by adaption (familiarity) [Ferwerda, 1998].
Shape information is directly derived from luminance, motion, binocular disparity, color, and texture, with luminance yielding shadow and subjective (illusory) contour information [Davidoff, 1991].
Shape perception is dominated by the curvature of the silhouette contour (figure-ground boundary) and 3D surface shading [Humphreys, 1992] with diffuse shading being the most important shape cue. Shape perception is highly orientation dependent such that rotated versions of the same form can be perceived as different shapes.
Perception can also be dependent on previous stimuli [Wünsche, 2004]. Familiar shapes and configurations can improve the recognition of a target if it is a part of them [Schiffman, 1996].
Depth perception is achieved using binocular vision and visual cues. Binocular vision includes disparity, convergence and motion parallax. Disparity depends on a object viewed by two eyes which are slightly displaced so that the perceived images differ slightly. The displacement of the retinal images of an object is converted by the brain to depth information. Motion parallax is the effect that the relative distance an object moves determines the amount its image moves on the retina. For visualization purposes binocular vision is achieved by

using stereo goggles or VR Head Displays. Independent of this visual cues such as size, brightness, perspective, overlay, texture gradient, and aerial perspective [Humphreys, 1992] are used to aid depth perception [Wünsche, 2004].
The concept of Gestalt originates from the fine arts and expresses the notion that the "whole contains more information than the parts". Perception of Gestalt is influenced by proximity, similarity, continuation, closure, symmetry, reification and *the law of prägnanz*, which states that the eyes tend to see the simplest and most stable figure [Schiffman, 1996]. Humphreys [1992] states that context might also play a role in Gestalt perception. A few examples can be seen in Figure 4.3.

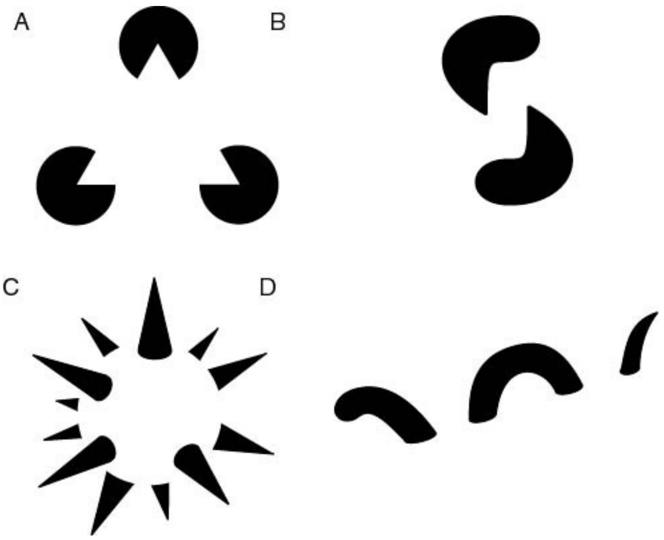



**Figure 4.3:** **A**: triangle will be perceived although not drawn
**B** & **D**: the eye will recognize disparate shapes as "belonging" to a single shape
**C**: complete three-dimensional shape is seen, where in actuality no such thing is drawn
Reification can be explained by progress in the study of illusory contours, which are treated by the visual system as "real" contours [Lehar, 2005]

Figure-ground perception describes the observation that an object can be instantly separated perceptually from its background. This is due to physically different attributes of the figure and the background but is also influenced by size, angle, and association with meaningful shapes [Schiffman, 1996].

## 4.4 Auditory and Haptic Features

For example when dealing with multi-sensory displays one can think of an equivalent to retinal variables as:

- tone pitch
- sound intensity, loudness
- position
- timbre
- tonality

Bregman [1994] wrote that there are many cases where those auditory variables are similar to the classic retinal variables (gestalt theory, figure-ground phenomenon, ...).
There are also comparable variables for haptic infromation - e.g. force, surface, ... - which again get important with multi-senory systems.

# Chapter 5

# Frameworks

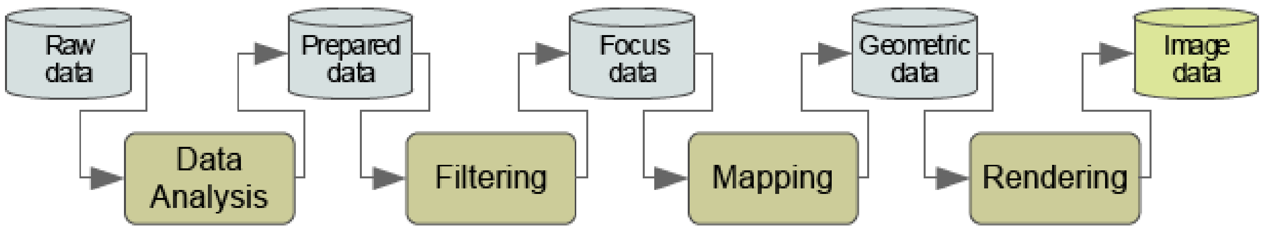
## 5.1 Automated and Rule-Based Systems

To assist the designer with the creation of visual representations computer assisted methods incorporating the principles of the retinal variables were developed. For an automated system, the available data has to be presented to the system in a specific form, e.g. data tables. Reference models for visualizations give an overview of the process. As data tables and the visualization pipeline closely related to automatic generation, they are described below.

### 5.1.1 Visualization Pipeline

To assist the designer with the creation of visual representations computer assisted methods were developed. The typical process flow from raw data to a graphical representation is shown in the so-called visualization pipeline as shown in Figure 5.1.

**Figure 5.1:** Visualization pipeline according to [QtrNsq and Card, 2007].

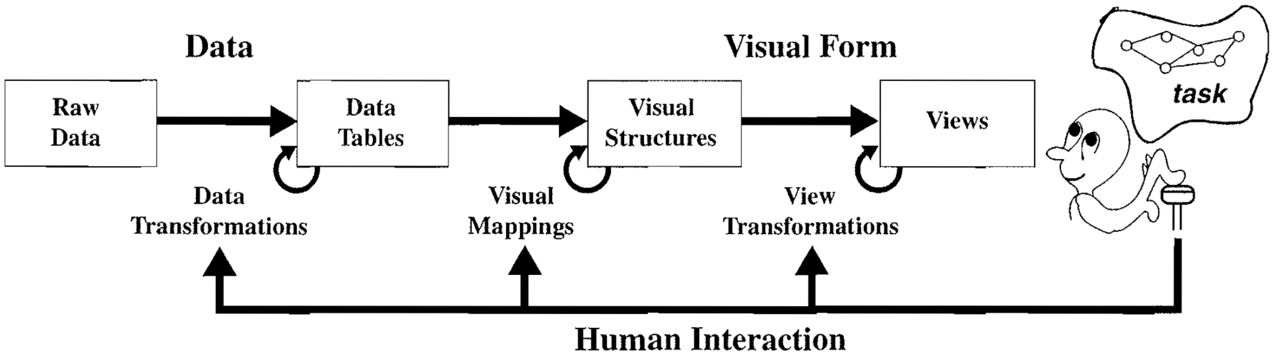



The process of data analysis is usually done mostly automatically, the data is checked for missing values etc. Filtering is usually done by a human who chooses the part of the availabe data is to be visually represented. During the mapping step the geometric form and attributes are chosen, e.g. size, color, position. Rendering performs the actual generation of the image data.

A reference model for visualization very similiar to the above is used in [Card et al., 1999], shown in Figure 5.2. It shows the different steps needed for the transformation of the raw data into meaningful graphics as well. However, it also shows that the raw data is saved in data tables after it is transformed.

The specific stages are defined as the input raw data, which is availabele in a data format specific to the type of data. After the transformation the data is represented in data tables and includes metadata about it. The visual structures stage strongly corresponds with the geometric data stage in Figure 5.1, spacial substrates, marks and graphical properties are defined here.

**Figure 5.2:** Reference model for visualization.




### 5.1.2 Data Tables

In a data table not only the relation of data is described but also metadata about the contained data is included. The following sections give an overview of properties of data tables in view of their use with automated generation of graphics. An exhaustive overview of data tables and possible transformations of them is beyond the scope of this paper. Detailled information can be found in [Card et al., 1999].
Figure 5.3 shows a simple example of a data table where the actual data is containd in the inner fields marked by *Value*. The labels *Variable* and *Case* are metadata.

**Figure 5.3:** A basic data table [Card et al., 1999].
(The double line on the left distinguishes the data tabe from a normal table which might be the end result of a visualization process.)

| | $\text{Case}_i$ | $\text{Case}_j$ | $\text{Case}_k$ | |
|---|---|---|---|---|
| $\textit{Variable}_x$ | $\text{Value}_{ix}$ | $\text{Value}_{jx}$ | $\text{Value}_{kx}$ | ... |
| $\textit{Variable}_y$ | $\text{Value}_{iy}$ | $\text{Value}_{jy}$ | $\text{Value}_{ky}$ | ... |
| ... | ... | ... | ... | ... |

#### Metadata

Metadata is data about data. It is necessary for an automated visualization process. In Figure 5.4 the row and column lables are metadata. Depending on the nature of the dataset, also the order of the labels can be metadata. But not only labels are metadata, also information about the type of value falls into this cathegory. In the figure an additional column with such information is added (N, Q, and O variable types).

#### Variables Types

[Card et al., 1999] orders variables into one of three basic types and additional sub-types:

- Nominal variables (N)
  A loose, unordered set of values, e.g. names. Names could be transformed into an ordered form (O) by sorting them lexicographically.

**Figure 5.4:** An example ([Card et al., 1999]) for a data table about films including a column for metadata (left of the double line).

| | | | | |
|---|---|---|---|---|
| *FilmID* | N | 230 | 105 | ... |
| *Title* | N | Goldfinger | Ben Hur | ... |
| *Director* | N | Hamilton | Wyler | ... |
| *Actor* | N | Connery | Heston | ... |
| *Actress* | N | Blackman | Harareet | ... |
| *Year* | $Q_t$ | 1964 | 1959 | ... |
| *Length* | Q | 112 | 212 | ... |
| *Popularity* | Q | 7.7 | 8.2 | ... |
| *Rating* | O | PG | G | ... |
| *Film Type* | N | Action | Action | ... |

- Ordinal variables (O)
  Can be ordered, e.g "small", "medium", "large". Ordinal variables can be used as nominal variables (N) by ignoring the order. A specific subtype is:
  - Ordinal Time ($Q_t$)
    Used to describe a point in time.
- Quatitative variables (Q)
  It is possible to do arithmetic on them, e.g. time. As there are different aspects of quantity, the following sup-types are used:
  - Quantitative Spatial ($Q_s$)
    Common in scientivic visualization.
  - Quantitative Geographical ($Q_g$)
    Used for geophysical coordinates.
  - Quantitative Time ($Q_t$)
    Used to describe a length of time.

### 5.1.3 An Architecture for Rule-Based Visualization

It is crucial that retinal variables are used properly. A wrong coice can make a graphic more difficult to interpret and even give false impressions about the data. Percepual rules have to be obeyed. The backgound is explained extentively in chapter 4, Perception.
[Rogowitz and Treinish, 1993] described an architecture for rule-based visualization. It uses metadata about the given data to decide which retinal properties are best suited for it to be used. The implemented system assists the user to choose retinal variables which fit the data. Though there exist more recent tools, this example is very well suited for demonstrating the basic principles.
Metadata can either be provided with the data set (e.g. extra columns in the data table) or automatically retrieved by analyzing it. If the kind of data to be presented is known, certain decisions about the representation can

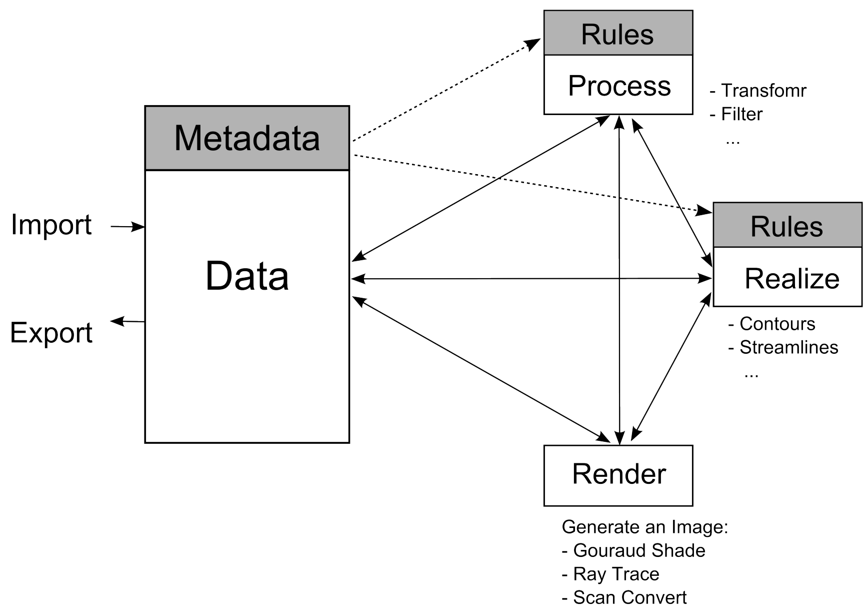
be made. Figure 5.5 shows an example of how representations can be chosen according to the availability of discrete or continuous data. Other such features could be dynamic range, spacial coherence, standard deviation, etc.

**Figure 5.5:** Visualization strategies ([Rogowitz and Treinish, 1993]).

| Dimension/ Rank | Example Data Types | Discrete Strategies | Continuous Strategies |
|---|---|---|---|
| 2/0 | temperature | multiple xy<br>xyz (scatter)<br>xy color | contours<br>deformed surface<br>image |
| 2/1 | wind | arrows | ribbons<br>particle advection<br>streamlines |
| 2/2 | stress | color arrows | color stream lines or ribbons |

Figure 5.6 shows a visualization system. [Rogowitz and Treinish, 1993] extended the more traditional system by adding metadata. It provides input for the rules which control the processing and realization. Those rules limit the choices of the user.

**Figure 5.6:** Metadata flow ([Rogowitz and Treinish, 1993]).




In Figure 5.7 the choice the user has is shown on an example of a colour map. He or she can either use the colour map set as the default or use a rule based version.
Figure 5.8 shows the implementation of the system. If the rule based path is taken, the system provides several candidate colour maps. The maps have been selected using metadata input.
This architecture focuses on rules based on relatively simple characteristics of the data, like luminance and colour maps. However the system is extensible to handle more types of data, even the inclusion of auditory or tactile data could be possible.

**Figure 5.7:** Rule based example: choice of colour map - perceptual flow([Rogowitz and Treinish, 1993]).

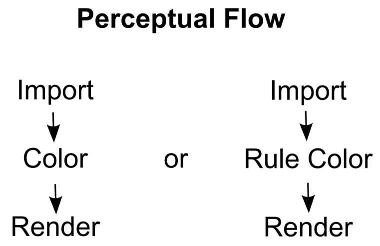
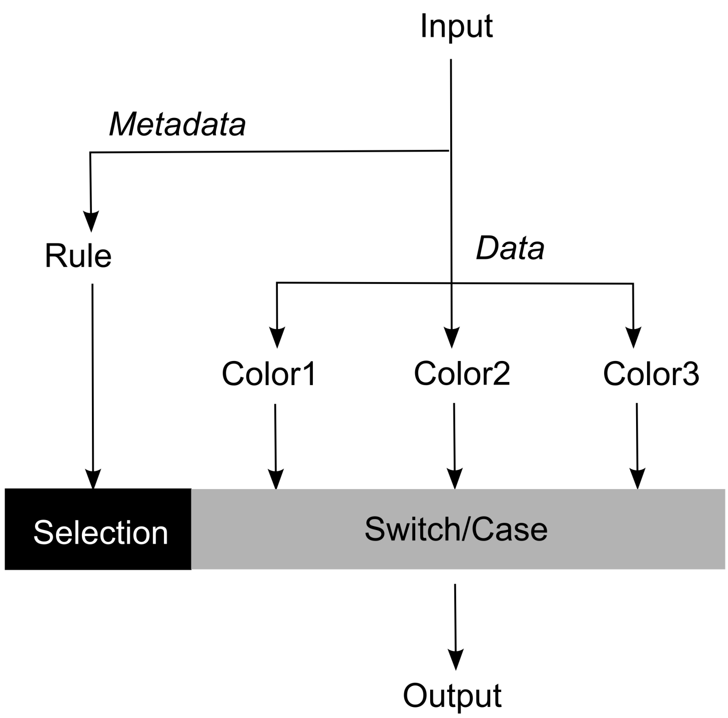



**Figure 5.8:** Rule based example: choice of colour map - implementation ([Rogowitz and Treinish, 1993]).




### A History of Rule-Based Visualization

Card et al. [1999] and Chih and Parker [2008] mention a multitude of tools and give an overview of the historical development of features of automated visualization.
Mackinalys thesis APT (A Presentation Tool) is used as the basis for additional work on automated visualization systems and implements Bertins theory on retinal variables. Since then more systems for automated or assisted generation of information visualization have been newly developed or are based on APT. Extensions include the addition of a representation of tasks, handling large amounts of information and handling more complex and larger amounts of data. Features for improved user interaction an possibilities to focus on selected areas of the data were developed. The Morpherspective tool (Chih and Parker [2008]) focuses on displaying data in a persuasive way, it is optimized to convay a special point.
In general the focus of the developments was on the automaed matching between data types and the correct graphical representation in order to communicate the intent and archieve cognitive amplification. (Chih and Parker [2008]) chellanges the use of the traditional retinal variables and states that images convaying the meaning of it might be advantageous (e.g. in a weather forecast table). This has the advantage that keys can be

ommitted. But due to the usually increased use of colour and complexity of the icon the visualization might loose experessiveness if transferred to other representation forms (e.g. conversion to black and white).

# Chapter 6

# Interfaces

Designing good interfaces helps to enhance the usability of systems. Interfaces shoult be easy to use. Retinal variables help to create such easy-to-use interfaces but on the other hand, graphical interfaces can be worse than their non-graphical interfaces. [Mackinlay, 1988]

## 6.1 Introduction

We have to use dozens of interfaces in our daily life. If you want to buy a bus-ticket oder buy a coffee at the vending-machine, you have to interact with a system. The intuitive usage of systems can help to:

- increase efficency
- increase safety
- increase the usability for people with limited reading skills

**Figure 6.1:** **A**: very simple Interface,
**B**: komplex interface

## 6.2 Interfaces on Desktop PCs

Modern computersystems offer widespread possibilities for HCI-designs. High-resolution screen and audio in- and output-devices are examples for such modern devices. More and more jobs in the working world require the work with an computer. Intelligent interface-design with simple retinal-variables can bring an big effort here.

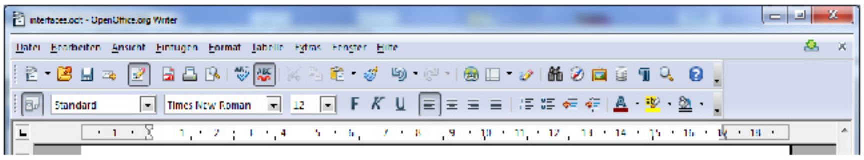



**Figure 6.2:** **A**: A classic bar in an text processing software. Buttons differ in shape, size, color, ...

## 6.3 Mobile-Devices

Interfaces for mobile devices face developers with other problems than in personal-computer systems [Volker Paelke, 2003]. This differences can be:

- Limited resolution
- Small display size
- Limited number of available color
- Limited processing power
- No standard input devices
- No full keyboard
- No mouse
- Specific interaction techniques
- Auditory enviroment
- Visual enviroment
- Level of attention

### 6.3.1 Resolution

While desktop-computers have megapixel-resolutions, mobile devices are limited in their resolution to a few hundred pixels per direction. It is more difficult to display big sets of information on the devices.

### 6.3.2 Display Size

Because of their small size, mobile devices have a limited display size what makes it harder to develope applications.

### 6.3.3 Colors

The limited numbers of available colors reduce the possibilities to use bertins variables efficent. Many devices have gray-scale-displays. This circumstance makes it impossible to create selective groups per the color-variable.

### 6.3.4 Processing Power

The limited processing power of mobile devices and often the limited bandwidth of these, require feedback-functions. To handle this operations, bertins ideas of simple visualization methods can bring an enormous usability advantage. Even on the devices with very limited display colors and processing power, it is possible to display progressbars.

### 6.3.5 Input Devices

Mobile devices do not have input devices like full-keyboards or even a mouse. Because of the different input devices of mobile devices, it is hard to develop interfaces, working on all different kinds of mobile devices.

### 6.3.6 Interaction Techniques

Mobile devices offer different interaction methods. Interfaces can be used through voice or image recognition. Modern devices, for example, offer possibilities to interact with the device through simple movements.

### 6.3.7 Enviroment and Level of Attention

In contrast to the use of a desktop-pc, mobile devices are often used in harsh conditions. Noise and bad light-conditions make it harder to use.

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