Palmer, Bruce, and Andrew U. Frank. "Spatial Languages." Paper presented at the Third International Symposium on Spatial Data Handling, Sydney, Australia 1988.

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1.0 Abstract

There has been considerable research and work in data structures while very little has been done in the information grouping area. This can be likened to deciphering a message in a unknown language with only the aid of a dictionary. Think how much additional information is present in the sentence structure and could be learned if a grammar book were available! The research currently underway involves looking at the way information is encoded in the structure of spatial data. For example, the structure of the chart could be diagrammed as we would a sentence. It is expected that different types of spatial information will yield different 'grammars' and that once these are known the processing of spatial data will be significantly enhanced.

2.0 Introduction

In this paper we will stress the informational aspects of spatial analysis and human reasoning about geometry and show how it can be used to organize our processing of spatial data. It is worthwhile to recall that reality does not have geometric properties, but that human beings induce these on the world, as they need these properties to structure their perception of visual information. Spatial analysis, including studies of geometry, are languages to describe geometrical aspects of reality as human beings perceive them. Thus different 'geometries' are possible, depending on the context and the subject studied. Different sciences and professions have created their own methods to view geometric properties of reality. They have established particular properties that they are interested in and have established a terminology for discussion. The difference between these 'geometries' can be likened to the differences between the languages of English and Spanish. One can express the same ideas in either language, but the vocabulary and syntax will not be the same.

For a single geometric fact we may give many different renderings, as we may use many different sentences to convey the same information. Thus geometry is not conceptually different from other methods of human communication.

The common meaning of a statement (geometric or not) and its various paraphrases, stating the same facts but in other terms, is often called the 'deep structure' of the sentence (Chomsky, 1972).

Generally one uses methods to describe geometric objects that are most of the time not adequate by the following yardstick: given two descriptions of the same geometric concept (the 'deep structure') it should be possible to detect the similarity in the description. Thus given descriptions for two graphs, it should be possible to see, that they represent the same information. This is not easily possible, if one of the graphs is given as a raster image, the other as a set of lines and characters. However it becomes substantially simpler to understand any similarity, if one describes two graphs as [a] the rendering of the data in a table by the 'line chart options i,j,k...' and [b] of the rendering of the data in the same table by the 'bar chart options l,m,n...'. We consider here the graphing package as a high level function applied to the data to transform it into a graphic rendering. Thus the similarity in the output is explained by the similarity in the input to the two programs. The differences in the output is then all due to the different options selected.

3.0 Geometry as a Language

When one discusses ways of communicating information, linguistics may provide us with some insights and a conceptual structure for use in our imaging analysis. We have used linguistic theory only for its descriptive analogies and the comparison will not be extended in any workable depth. However, when mathematically precise statements can be shown to be transferable from linguistics to spatial studies, we will not hesitate to use those results for our own use.

3.1 Differences between linguistics and spatial communication

Unlike linguistics, which deal with man-made communication via spoken utterances and written words, spatial languages have to deal with both man-made images and images not produced by mankind. From this perspective two very different objectives emerge as the analysis depend on where the image originated. If the image is man-made then the objective is to reconstruct the message or information that the creator of that image intended to communicate. For example, blueprints, logic schematics, maps, are all images which have been generated by humans and have a identifiable and constrained message. Contrasting this is 'natural', or non-human generated images. The objective of this type of analysis is to extract information guided by the wishes of the interpreter. There is no intended message, any number of different sets of information can be said to be included. Even worse, the only structure is that discovered or imposed by the viewer. There are no previously agreed upon conventions inherent in the image to guide our analysis. Images in this class include any image that includes real-world scenes.

We will be investigating charts as a representative man-made visual information carrier. Charts can be said to be a well developed, mature way to communicate certain types of data. Most scientists are familiar enough with charts to quickly ascertain the primary message that the creator intended if 'normal' convention is followed. It is the discovery of this 'norm' that will give us the vocabulary and syntax of charts.

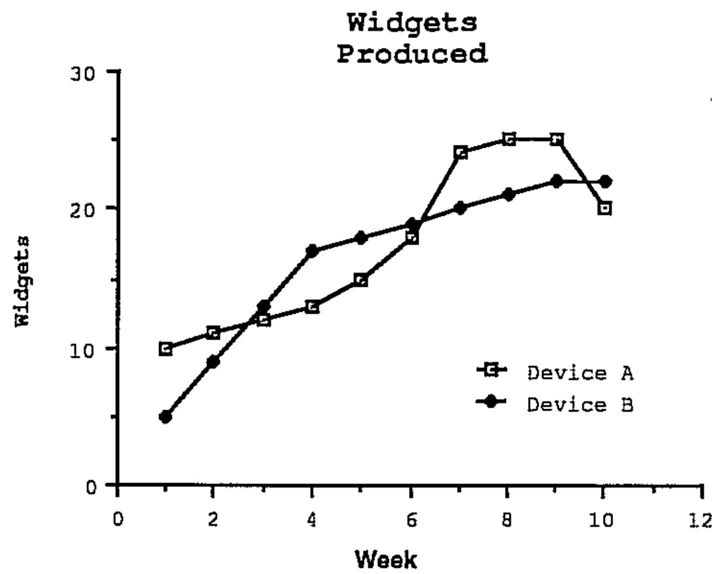


Figure 1

3.2 The deep structure of a language

There are many sentences possible that can be used to convey a set of information. These sentences can vary widely according to many factors. Visual communication also has many factors that affect the delivery and interpretation of its message. Different images may be generated from the same information, revealing essentially the same geometric properties. As an example, one can consider a set of information represented by the graph in

Time	Device A	Device B
1	10	5
2	11	9
3	12	13
4	13	17
5	15	18
6	18	19
7	24	20
8	25	21
9	25	22
10	20	22

Data for charts

Table 1

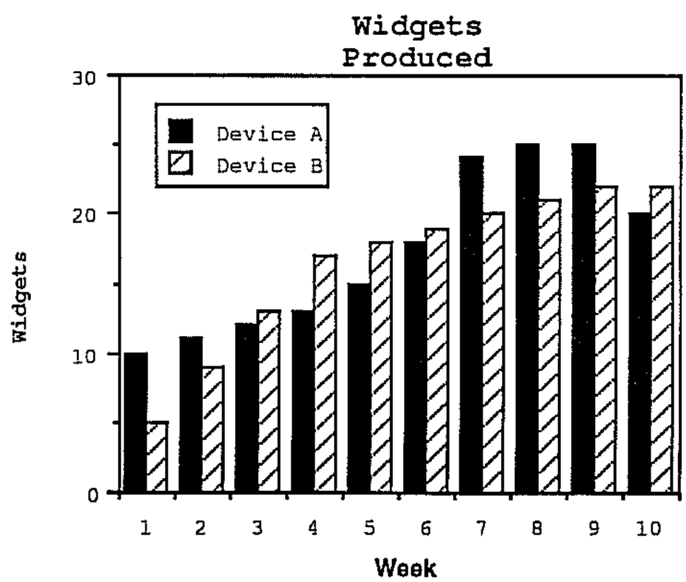


Figure 2

Figure 1. The same information content can said to be included in the bar chart shown in Figure 2. The two graphs are obviously up to a certain limit equivalent in their information content, or in their deep structure. One may think, that the deep structure is equivalent to the table (Table 1) which was used to construct the charts, but this table is just another representation for the same deep structure (information), but this time not a primarily geometric one.

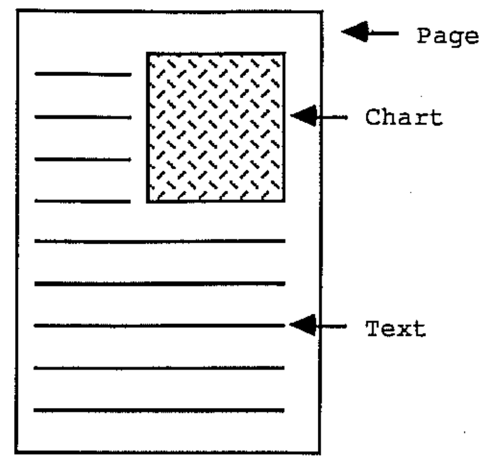


Figure 3

4.0 Basics of a Spatial Language

It is the structure in combination with objects that convey information. We may not assume that all objects have a fixed meaning. The information content of many objects is only given by the context they can be used in and their actual context. In this case we will be substituting graphical objects as equivalent to words. Words do not mean things by themselves, only in connection with other words (Wittgenstein, 1966). The possibility of understanding is quite closely tied to our understanding of rules of language which allow us to construct paraphrases and formally set a context for words to have a certain meaning.

4.1 Spatial objects

As a simplification for this paper, we will not be inquiring into what composes basic spatial objects. We will assume that simple objects such as lines, polygons, and characters are all available to construct more complex objects with significant information content.

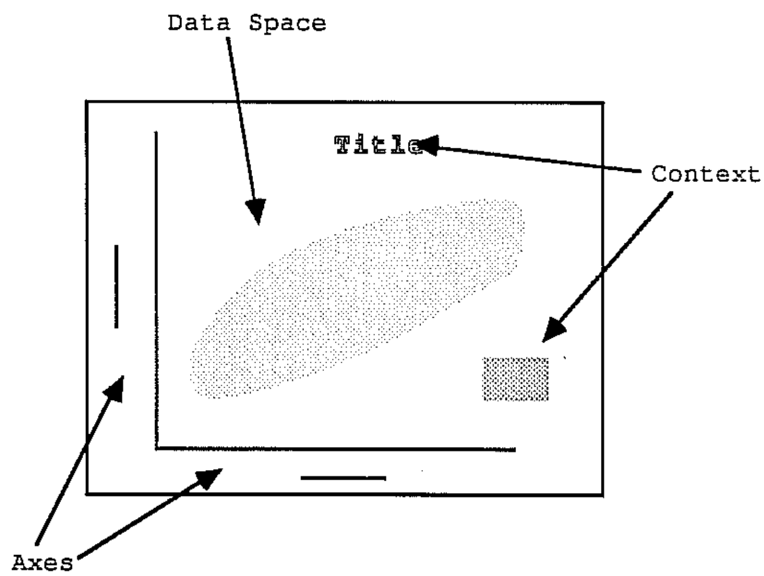


Figure 4

4.2 Properties of space

In order to deduce the syntax of spatial images there are a number of properties of space that must be considered. The first of these is that as encoded and interpreted by humans, space is not as simple as classical geometry defines. The first property is that of non-linear mapping of one space into another. That is, we change the origin, scale and continuity of objects as often as is necessary. A second property is that of the various pieces usually do not directly interfere with one another unless some links or connection is to be made. These two assertions are evident in several ways in a chart. It is worthwhile to illustrate these points by means of a series of caricatures of a chart on a page.

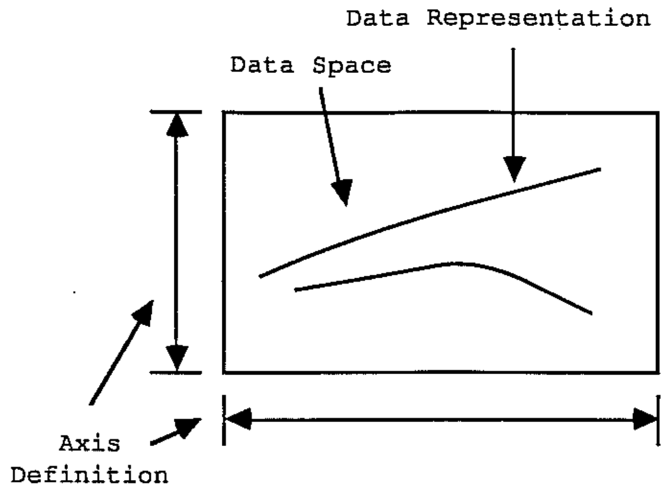


Figure 5

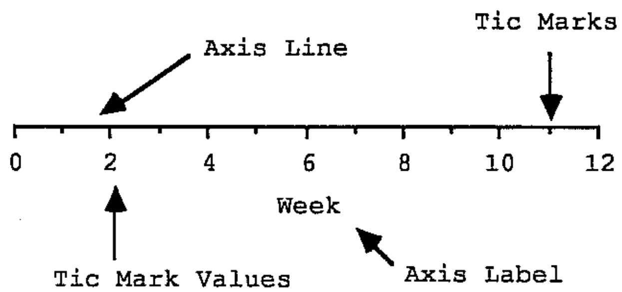


Figure 6

4.2.1 Chart mappings

Looking at Figure 3 we see a chart as it would be located on a page of text (observe the self-recursive nature of this example). The text is done using its own scale for character size, margins, etc. while the map does not share any of those qualities within it. We also observe the text does not in any way intrude on the space occupied by the chart. Moving on to the chart itself we can see two distinctly different mapping of space for the entire chart (see Figure 4). We observe a data space surrounded by the axes and context. Here we notice that while the axes do not intrude onto the data space other portions (called context) overlay into the data space. At the same time they do not interfere with the representation of the data. The scale, etc. implied for the data space is defined by the axes (Figure 5). The axes and other parts are in a different coordinate system altogether. As anyone who has produced a chart by writing their own program will testify, it is easiest to make by first defining (by using a graphics package 4 X 4 transformation) a data space into the devices coordinate system. After the data has been graphed, a second space is defined by a new 4 X 4 transformation to produce the other pieces of the chart, especially the detail involved with the axis (Figure 6). Again here we notice that the various parts of the axis do not interfere with one another.

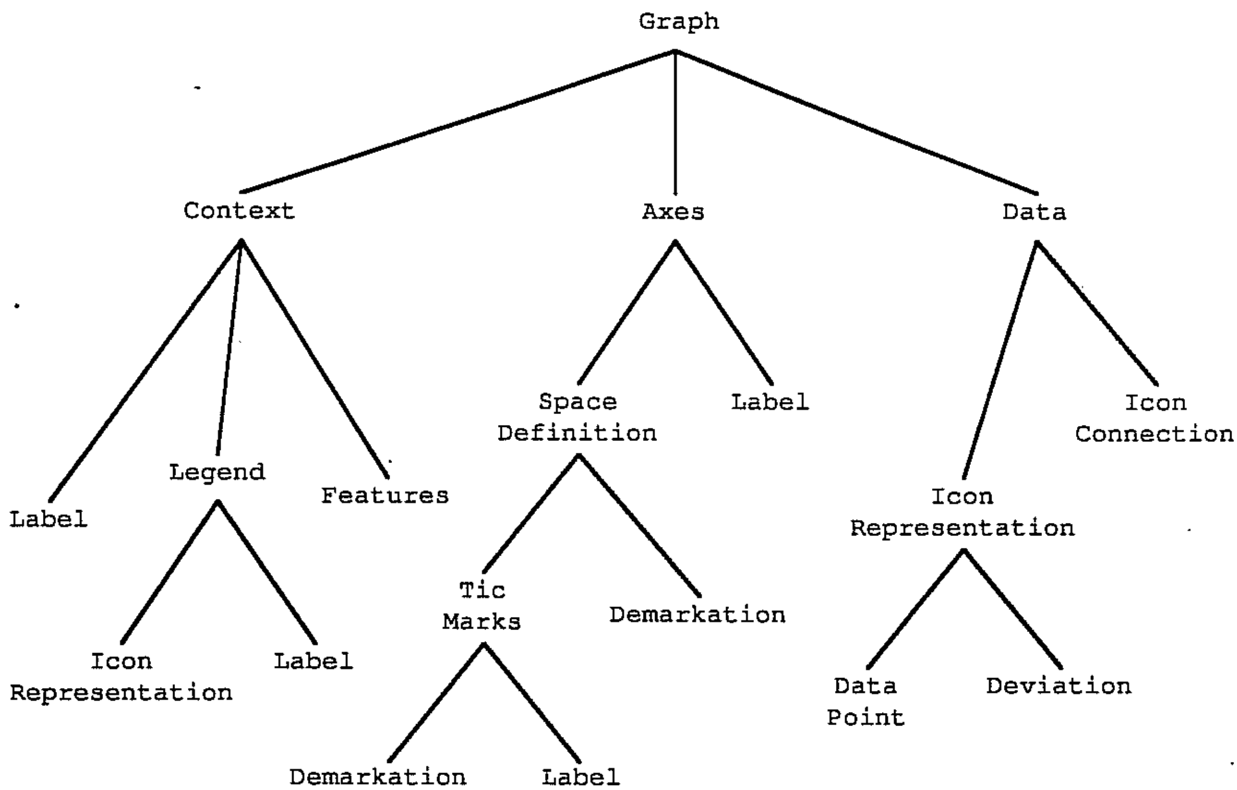


Figure 7

5.0 Chart language

As an example of a language which can be said to take an abstract set of of information and represent it in a spatial pattern, a set of rules to make a chart are described. These rules are intentionally incomplete but they are intended to be illustrative of an approach.

5.1 Chart Components

It is useful at this stage to introduce the various pieces that comprise a chart. A hierarchical diagram that shows the relationships of the parts is shown in Figure 7. Figures 4 - 6 also show pictorially the components of a typical chart.

5.2 Phrase Structure Rules

Tables 2 and 3 show chart rules that can be considered as equivalent to linguistic phrase structure rules. Several things should be noted: first, that most of the components are context-sensitive in both a global as well as local

1) Sets of data with which [n] relationships are to be mapped into a [n] dimensional space.
2) A set of [n] axes which provide the definition of the [n] dimensional data space.
3) A context in which the graph data is to be viewed.

Semantic rules for a chart
Table 2

1) Each data point has a [n] tuple set of values which are mapped into [n] dimensions and presented by an icon.
   a) Different data sets may be overlaid in the same data space by [m] different icons.
   b) Data points may be connected by a [n-1] dimensional object which represents an ordering of the data points.
   c) Data points may be represented by a object of up to [n] dimensions which relate ambiguity into positional imprecisness of the [n] tuple values.
2) A set of [n] axes, each of which:
   a) Defines the parallel of a dimension of the data space.
   b) Tic marks represent specific values on the axis, which defines the translation, scale, and linearity of the data space for that dimension.
   c) Individual tic marks may be labeled with text to give their value.
   d) Is labeled to show which data tuple value is represented by that axis.
3) The context of the graph, presented by multiple disjoint components:
   a) A title for the overall graph.
   b) A legend, which ties the [m] icons to their individual data set.
   c) Optional features, used to highlight some aspect of the graph (for example, an arrow pointing to a particular data point of interest).

Component rules for a chart
Table 3

sense. Second, that many of the components are optional in the same sense as one can make a sentence more descriptive by adding adjectives and adverbs. For example, in Figure 8 the error range of the data points are shown by adding deviation bars to the data icon.

5.3 Removing Ambiguous Information

Whenever one draws a crude chart there is always some question as to how some components may be interpreted. For example in Figure 9 we would assume because of the ragged axes that it was a hand drawn chart and would be surprised if the data was as irregular as shown. On the other hand if the axes were drawn with a straightedge we could not be sure without other information (for instance, a label telling us this was daily stock prices for the last two years) if the small fluctuations were due to lots of data points or a shaky hand while drawing. If we look at Figure 10 we are reasonably sure (even if it were computer generated) that the curves in the lines are extraneous and there are really just 8 data points. The opposite case is where a smooth line (fitted curve) can give the impression of multiple data points. Figure 11 shows 8 data points fitted with a 5th order polynomial curve. But yet even without reading any labeling we can ascertain that the data is not that smooth.

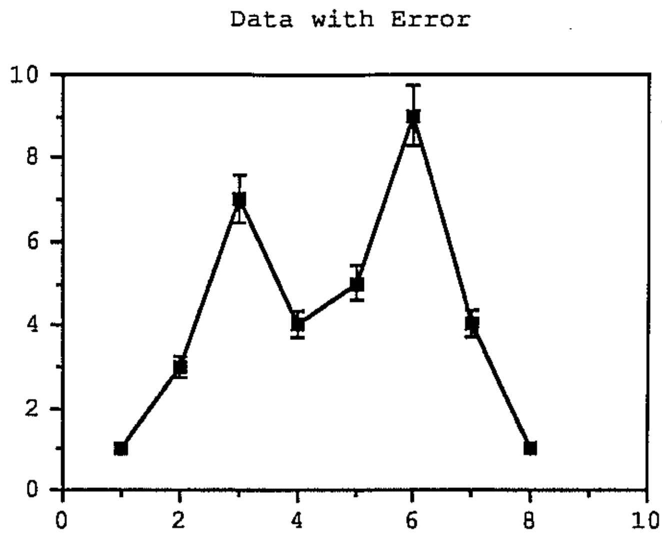
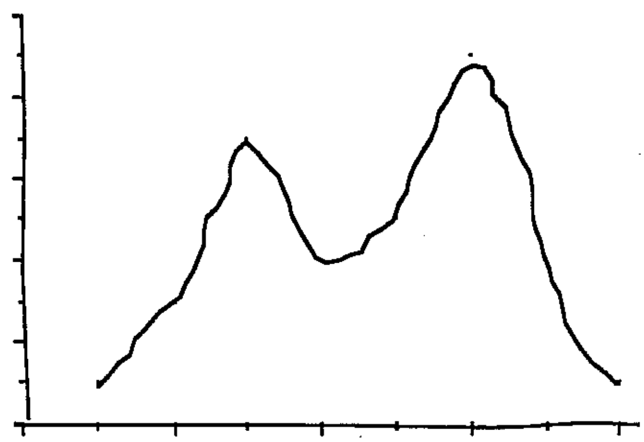
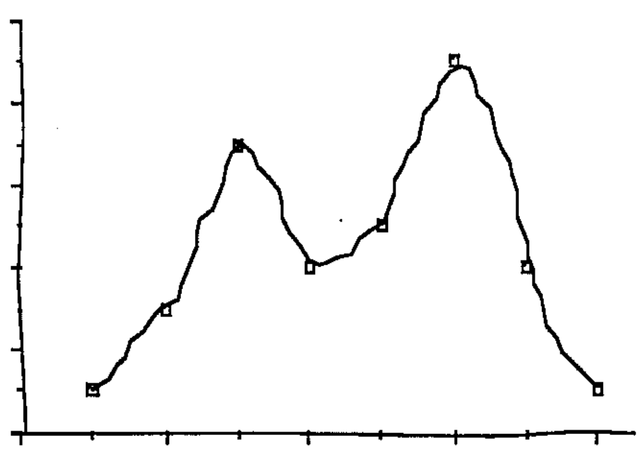


Figure 8



Ambiguous

Figure 9



Ambiguity Removed

Figure 10

6.0 Conclusions

While charts are not the most complex images that are available they are a good example of information encoded by humans into a spatial form. We have shown how looking at space using techniques developed by linguists can aid in our understanding of how and why certain spatial relationships exist. There remains considerably more work on spatial information grouping of man-made images before we can begin to understand how humans might interpret natural images. On the other hand, interpretation of man-made images occupy considerable attention amongst researchers today. It should be possible to use and extend these techniques for use in determining the grammar of other images. We can then begin to see when particular image understanding techniques should be applied.

References

Chomsky, N., 1972, Studies on Semantics in Generative Grammar, The Hague: Mouton,

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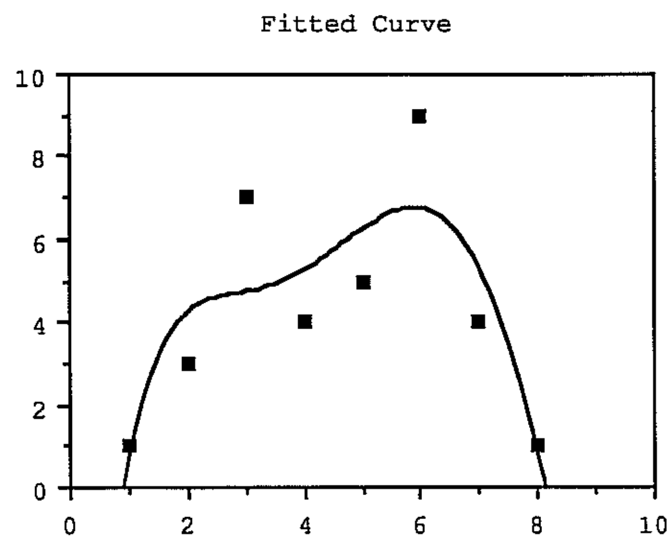

Figure 11