

1 The Big Picture

In this paper, Wertheimer outlines a series of factors that impact the way in which we group both visual and auditory objects. In certain cases, the interactions of these factors are discussed. The paper is very much anecdotal, as the factors are "proven" by providing examples of them and then proclaiming the factor to be true in the general case.

2 The Gory Details

The first factor that the author addresses is that of proximity. In the case of visual groupings the proximity is spatial, whereas temporal proximity is used in the auditory case. The given examples of this factor consist of black dots with very regular arrangements. If proximity is truly the only factor working here, then it seems that irregular arrangements should be presented, as well.

Similarity is the second factor, and is illustrated by introducing a second type of object: a circle with black perimeter and white interior. Not surprisingly, when proximity is held constant, the obvious groupings are the ones arising from each object's appearance.

The third factor is called the Factor of Uniform Density (or Common Fate), which is a strange phrase to describe a very simple concept. The basic idea is that things in the same group will tend to move as a group. Conversely, things that move with the same speed and in the same direction will be perceived as belonging to the same group.

Now that motion has been introduced, it is valid to ask how groups change as their component objects move. We're given an example of proximity-based groups that change as the objects gravitate toward peers in other groups. This introduces the Factor of Objective Set, whereby groups are perceived at times when, were it not for their cohesion at an earlier time, they would be considered independent.

After all of this, Wertheimer finally gets around to what he calls the Factor of Direction. Basically, the idea is that points will be perceptually grouped with others so that they form some "nice" structure. In our mathematical terms, the idea is *almost* that they form curves with continuous curvature. The one example that doesn't fit this mold is given in his figure 13, which shows a square wave. While the curvature of the square wave is certainly not continuous, its discontinuities are certainly periodic. The author does not attempt to rigorously define this factor, so the reader is unsure how periodicity and continuity of curvature relate to the abstract notion of "direction".

The next two factors are introduced in rapid order, and aren't particularly well defined. With respect to curve segments we are given the Factor of Closure, which says that we group such segments to form closed objects - most of the time. Moreover, when two objects intersect, we tend to see the intersection as belonging to both objects.

The Factor of Good Curve is thrown in almost offhandedly, in order to explain an exception to the Factor of Closure. We are shown a square wave with a parabolic shape superimposed upon it. The groupings due to closure don't dominate, we're told, because the curvature overpowers them.

The final factor that Wertheimer introduces is that of Habit. Essentially, if we are used to seeing certain things in certain arrangements as forming groups, we will search out such groups

in the presence of clutter. The most interesting example in the paper shows two letters in an uncommon arrangement, so that they aren't interpreted as letters because, the author implies, other factors are in effect.

In addition to introducing these factors, Wertheimer looks at some of the interactions between them. In general, they can either cooperate or be in conflict.

An example of conflict is presented between Proximity and Similarity, where dissimilar objects are in close proximity to one another. By not commenting, the reader is to assume that the conflict results in a stalemate. In later examples, where similarity is supposedly the victor, we are presented similar objects along diagonal lines. Again, the linear organization goes unmentioned.

3 The Scott Opinion

The style of this paper is certainly different than anything we'd expect to see in a modern journal. Wertheimer establishes his factors by anecdote, and provides no evidence of any experiments to confirm them. The paper's introduction is a bizarre philosophical jaunt with no obvious connection to the text that follows, somewhat like this sentence.

Leaving methodology aside, this paper does present ideas that are worth consideration because they can be applied to problems in computer vision. In particular, several of these factors translate naturally to the problem of image segmentation. Formally, given a set of pixels forming an image, we'd like to assign each to exactly one group. These groups correspond to high-level constructs within the image such as sky, grass, people, etc.

The Factor of Proximity is clearly the most important consideration here. The "correct" segments would correspond to objects with local coherence, so a given pixel is very likely to belong to the same group as its neighbors.

In any interesting case, though, segment boundaries must exist somewhere. The Factor of Direction, and specifically the notion of good continuation, gives some insight to what those boundaries might look like. If we assume that objects in the real world have "nice" boundaries, this factor could be used as a sanity check of sorts.

The Factor of Similarity, though it's formulation is somewhat vague, can be use to justify the creation of segments based on uniformity of color (or, more properly, hue). There are probably other interpretations of this factor that would be equally valid, but color is an obvious one.

If we extend the problem of segmentation to video sequences, the Factor of Common Fate becomes very useful. Notwithstanding the case where the camera is in motion, the direction and velocity of objects in a scene give a good indication of whether or not they belong to some larger group.

So we see that the factors that Wertheimer describes can be used for real world problems. When we do so, however, it's important to think of them as suppositions more than laws in the strict sense. The burden of proof for a law is certainly much higher than has been achieved in this paper.

While the factors themselves aren't particularly surprising, Wertheimer does us all a favor by listing them in the way he does. He starts to look at the interactions of multiple factors, but leaves a lot of room for further work to be done. Can we quantify the relative strengths of the factors? Are the relative importances of the factors the same for everyone or do they differ for individuals?

By introducing the factor of Habit, Wertheimer opens a new line of questioning. Are the relative strengths of the factors hard-wired, or are they learned through experience. Moreover, are the factors themselves learned? Hopefully others have raised and addressed these questions in the years since 1923.