Vehicle 9

Shapes

We will improve on our vehicles some more, along the lines outlined in the construction of the preceding brand 8, but with a different intention this time. We will try to furnish our vehicles with a convenient set of ideas referring to the shapes of things, especially to shapes as we see them with our eyes (and as a vehicle sees them if it is equipped with a good camera-type eye).

First of all, if we want to consider shape independently of color and other irrelevant details, we must produce an outline drawing of things in the visual field of the vehicle, as a draftsman would with a pencil. (Webster's dictionary defines shape as "the quality of a thing that depends on the relative position of all points composing its outline or external surface.") This is not very difficult if things stand out clearly against their backgrounds—for instance if these things are birds in the sky or vehicles on a white sheet. We can then use the trick of lateral inhibition, which we have already learned (figure 14). Only sharp boundaries will be passed on to the next level, thereby producing a pure line drawing. If the interior of the figure represented is quite homogeneous, say all black, there will be only the outline or shape.

Let us construct detectors for elementary properties of shape.

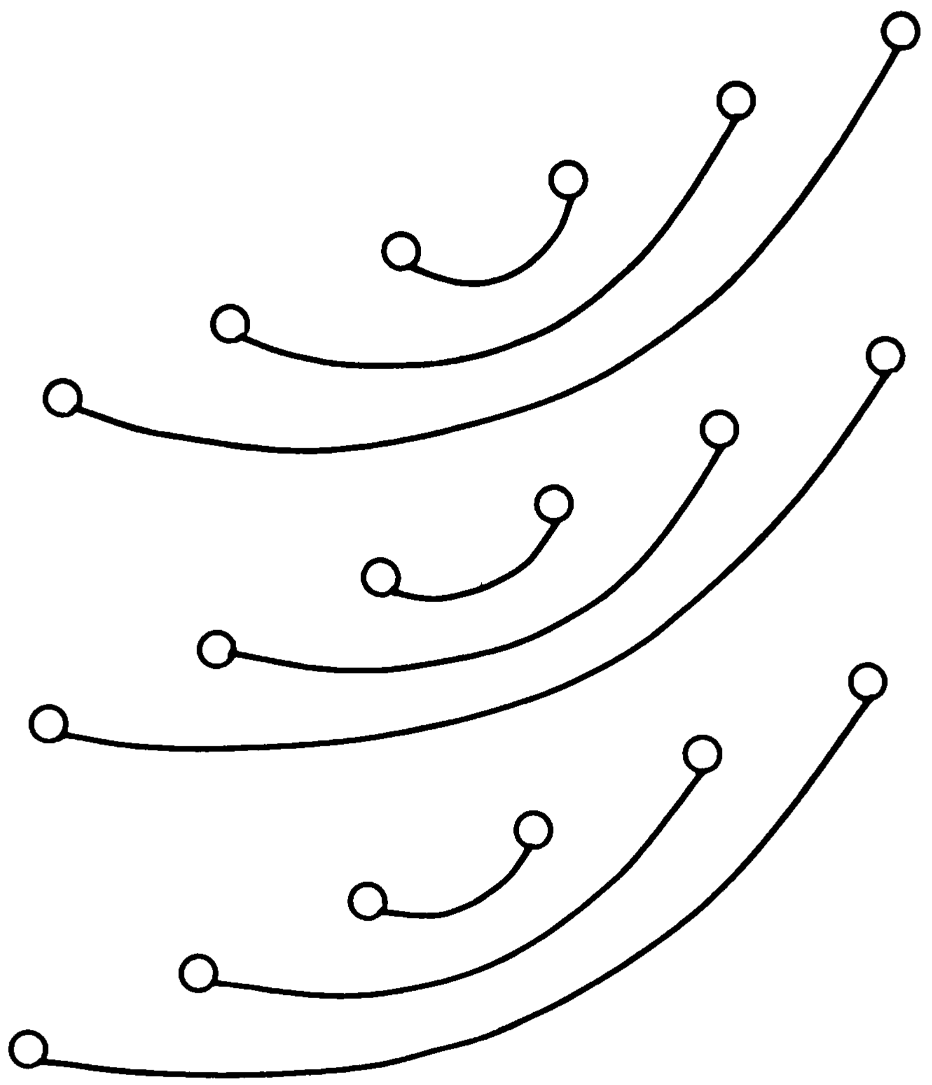

Figure 16
A detector for bilateral symmetry. There is an array of elements onto which an image is projected. Elements symmetrically spaced with respect to the midline enhance each other. There will be a strong activation of the array for bilaterally symmetrical images.

The first property that comes to mind is bilateral symmetry. Its detector is easy to construct and enormously valuable (figure 16). Again we make an array of threshold devices onto which a picture of the external world is projected by means of a suitable camera system (we can filter the picture first through a network with "lateral inhibition" to enhance relevant detail). One half of it receives a picture of the right half of the visual environment, everything to the right of the vehicle; the other half receives a picture of the left half of the world. Now we connect by a wire each pair of threshold devices occupying symmetrical positions on the right and left sides. Through the wire the threshold devices influence one another in such a way that when they both receive input, they become much more active than when only one of them is activated. It is clear now that when the vehicle faces a symmetrical shape (with a vertical axis of symmetry, such as an upright human figure seen from the front or from behind), there will be much more activity in this array of threshold devices than there will be in any other case. For every element excited on one side of the vehicle, its symmetrical element on the other side will also be excited, with the consequent reciprocal enhancement.

Let's not talk about an upright human figure; that introduces an unintended aesthetic aspect. Think only of a world populated by vehicles of the various kinds that we have been building. Up to now we have not talked much about the exterior appearance of our vehicles, although we have implicitly assumed that the vehicles are made of two halves, mirror images of one another: two motors, one on each side, two nostrils, a symmetrical casing like an automobile. Of course such vehicles, seen from the side, are not symmetrical: their sense organs are in front, their motors are in the back, and their prevalent movement is always in the same "forward" direction. Nor are the vehicles symmetrical in the up-down direction if they move around on surfaces, as our vehicles mostly do; for reasons connected with gravitation, there will be wheels (or other instruments of locomotion) on the side of the vehicles facing the ground, the so-called underside.

But there are good reasons for the vehicle to be symmetrical in the direction perpendicular to both the "front-back" and the "up-down" directions—along the axis defined by the pair of concepts "right" and "left." We have seen this early on in the cases of Vehicles 2, 3, and 4, which showed surprisingly lifelike behavior on the basis of paired, very simple, symmetrical connections between two sense organs and two motors. The kind of behavior associated with two symmetrical reins governing the motors is one in which an object is isolated from the environment as a partner in behavior. The vehicle's movements are directed by feedback, either turning the vehicle toward the object or turning the vehicle away from the object.

Consider the first case: feedback that makes the vehicle turn toward the object. An observer might say that our vehicle has that object on its mind or our vehicle pays attention to that object. Well, what if the object is another vehicle? What would the situation look like to that vehicle, and how should it react? Obviously the situation in which a vehicle sees another heading directly toward it, whether in an inquisitive, a friendly, or an aggressive mood, is a special case and well worth special attention. The detector for bilaterally symmetrical shapes, which we have just described, proves helpful here: we may connect it to the output in such a way as to trigger the mechanisms that govern the appropriate reactions to "another vehicle facing me" or "another vehicle having me in mind." (Perhaps one should reactivate the beautiful term "confrontation": fronts coming together, facing each other.) In fact, it is clear that bilaterally symmetrical configurations in a natural world containing only vehicles (and no other man-made objects, such as churches or monuments) would mostly signify just that: a partner in interaction with the observer.

There is a relation between bilateral symmetry in sensory (especially visual) space and the concept of "thou," the pronoun of the second person singular. This has been used by the builders of temples and churches who, by a pointedly symmetrical architecture, evoke the presence of an abstract thou, a partner in conversation always facing the observer. The same principle can be observed in biology: certain flowers, such as orchids, adopt bilaterally symmetrical shapes in order to be accepted as "partners" by insects with detectors keyed to this type of symmetry.

I want you to note that something new and very important has crept into our discussion of a detector with bilateral symmetry. We decided to give our type 9 vehicles a system of connections between corresponding points on their right and left sides. In order to explain how useful such a system would be, we had to invoke not only the external appearance of other vehicles (which our vehicle might meet) but their behavior as well. Things are getting complicated: we are no longer working on individuals taken by themselves but on the members of a community in which there are complicated interactions between vehicles of the same or of different kinds.

Every improvement that we invent for the latest breed of vehicles put in circulation will either force others out of business by a process of Darwinian selection (see Vehicle 6) or make others change their behavior through learning (see Vehicle 7). Of course, this makes it difficult to foresee what will actually work out as an "improvement." Sometimes the net effect will be contrary to what we expect, due to unforeseen reactions of the environment. But certain great inventions will survive all vicissitudes and will be immune to all shrewd defenses. I suspect that the detector of bilateral symmetry, which provides information about "being in someone's focus of attention," belongs to this category. Even in biology with all its complicated interactions between species, the symmetry detector has remained of primary importance. An insect in search of a sexual mate does not really care if it gets occasionally sidetracked by an orchid as long as its symmetry detector serves the right purpose in the majority of cases.

Other insects fall for different kinds of flowers, for those with radial symmetry, like daisies. We can also construct radial symmetry detectors for our type 9 vehicles: these detectors might indicate singularities in the world, sources from which something emanates in all directions. A radial symmetry detector could also be based on the fact that no movement is perceived on approaching a pattern like that of figure 17. The picture remains identical to itself.

A fundamental category of form is periodicity. A repetitive pattern may signify many important situations. It may signify a collection of identical individuals. Then again, a periodic pattern left on the ground may be the track of a vehicle moving by some sort of

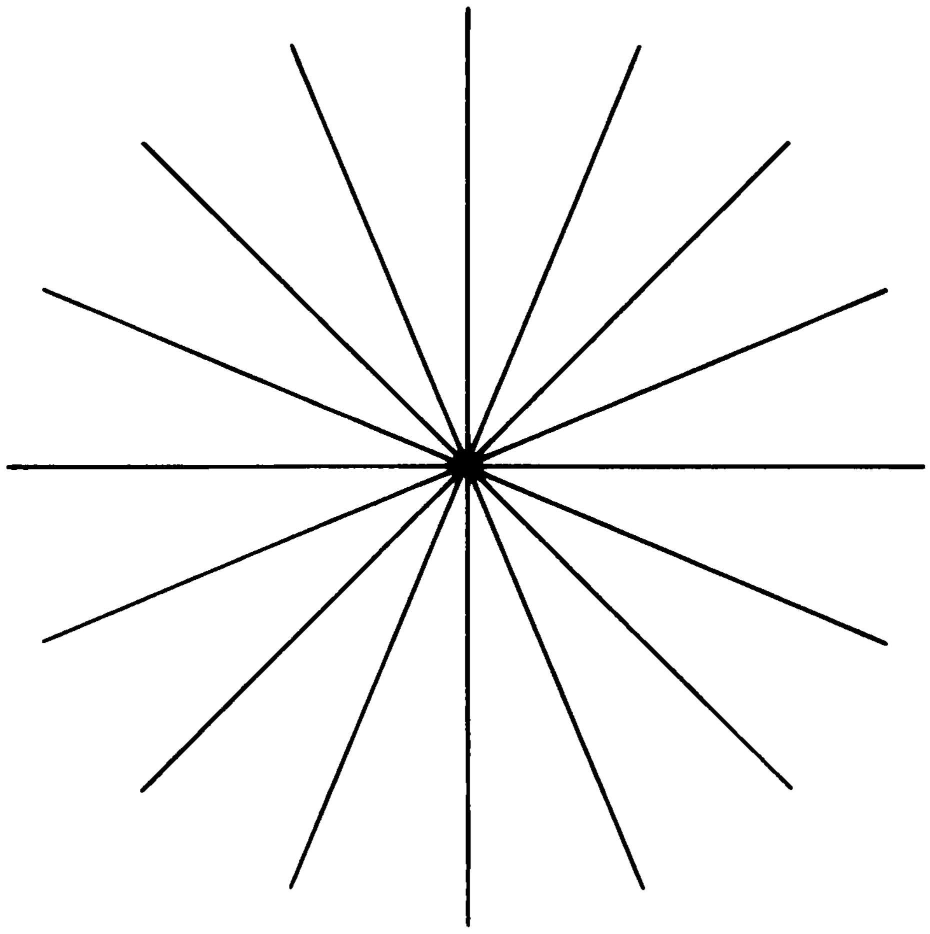

Figure 17
A pattern that is invariant to changes of scale. A vehicle approaching the center of the figure has a constant visual input (provided we make the figure large enough and the lines infinitely thin). The absence of perceived movement may be used as diagnostic for figures with radial symmetry.

periodic stepping mechanism. Or the pattern may be generated by some oscillatory movement in the form of a standing wave—an indication of stored energy. For all these reasons periodic patterns are happenings of great importance in this world; they are just as fundamental as bilaterally symmetrical or radially symmetrical figures. So we should equip our vehicles with detectors for periodicity.

This can be done in various simple ways. For instance, we can give them periodic templates with different spacing and let them match the picture of the environment with the templates by the mathematical process of *cross-correlation*. This is the principle of Fourier analysis. Its technical realization does not require too much ingenuity. Another interesting detector of spatially periodic input is implicitly contained in the network described in the previous chapter as lateral inhibition. We have seen that such an array of threshold devices neglects continuous excitation and enhances contrasts. It gives maximal output for patches of excitation spaced sufficiently far apart so that they won't disturb each other by inhibition. For a periodic pattern, the spacing is determined by the length and strength of the inhibitory connections. If we test the lateral inhibition device with striped patterns, we will notice that it gives the same output no matter how the stripes are oriented if the inhibition works in all directions.

Taken together, vehicles of types 8 and 9 have provided much new evidence for our law of uphill analysis and downhill synthesis. A problem that taxes the minds of psychologists when they deal with real animals or humans, that of inborn concepts, found many solutions when we attacked it from the downhill, synthetic direction. We built very simple homogeneous networks and then discovered that they contain implicit definitions of such concepts as 3-dimensional space, continuous movement, reality of objects, multitude of objects, and personal relation. More and more we are losing our fear of philosophical concepts.

The exercises in synthetic psychology contained in this chapter deal mostly with visual input. It is of course easy to imagine a priori concepts in other categories of input, such as the tactile or olfactory inputs. It is quite elementary to provide the vehicle with detectors of aural periodicity. They would detect various frequencies in the purely time-dependent (nonspatial) input derived from one of the vehicle's ears (microphones). The a prioris of frequency, the so-called resonators, have been basic to human auditory theory for a long time.