The Aesthetics of X-Junctions: Cognitive Constraints in the Art of Continuous-Line Caricature

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Abstract

This article exposes cognitive constraints in production and perception of caricatures drawn with one continuous line. Constraints in production enable an artist to overcome the complexity of connecting all individual line segments of a conventional caricature. Constraints in perception enable an audience to overcome the complexity of inferring three-dimensional edges and shapes from two-dimensional line segments. In both production and perception, constraints exploit X-junctions where the continuous line meets itself in crossing and tangent configurations that contribute to the aesthetics of these artworks.

As a visual artist and cognitive scientist, my work is concerned with the production and perception of line drawings. Historically, line drawings of animals are among the first forms of figurative art appearing on rocks and cave walls thousands of years ago. These early drawings are remarkably effective in representing depth as a third dimension and even time as a fourth dimension [1]. More recently, line drawings have been studied to understand how humans and machines can infer rich three-dimension shapes from sparse two-dimension lines [2]. These studies have highlighted the role of constraints, which enable inferences of shapes from lines based on probabilistic regularities of the real world and its projection to images [3].

It is not surprising that constraints would apply in perception, as viewers are otherwise faced with an infinity of possible interpretations. But it is surprising that constraints, which limit possibilities, can also support creative production [4]. In effect, constraints encourage artists to explore possibilities that they would otherwise not entertain, and to exploit regularities that can be recognized as such by audiences.

Here I focus on line drawings in the form of continuous-line caricatures (Fig. 1), which impose the extreme constraint that a portrait be produced in one line without lifting the pen from the page. To satisfy this constraint, I adopt additional constraints that introduce X-junctions, which are configurations where the continuous line meets itself at crossing or tangent points. These X-junctions play an important role in audience perception and aesthetic evaluation of the resulting artworks.

Fig. 1. Left and Right, diptych, continuous-line caricatures rendered as wire sculptures, 75 × 50 cm, 2018. (© Kevin Burns)

Production

To create a continuous-line caricature, I begin by drawing a conventional caricature (Fig. 2, upper) using curved line segments to exaggerate distinctive features of a face. Like most line drawings of faces and figures, these drawings contain numerous T-junctions where one edge is perceived as occluding another edge. Examples appear on the jaw lines at points that occlude neck lines (Fig. 2, upper left) and shoulder lines (Fig. 2, upper right). Then, using a self-imposed constraint, I convert each caricature to a set of closed loops (Fig. 2, lower), eliminating all T-junctions and line endpoints except for one open loop with two endpoints. Some loops may contain crossing points, and some loops may overlap others to create crossing points, but the key is that the loops are constrained to touch in a series of tangent points, denoted by dots in Fig. 2.

Finally, a continuous line is drawn in one stroke that traverses all loops by converting tangent points to crossing points, much like a figure 8 can be traced in one crossing stroke along two tangent figure 0s. In the final artwork (Fig. 1), additional X-junctions are introduced at near-tangent locations by bringing the continuous line into tangent or crossing contact with itself.

The intermediate step of redrawing a conventional caricature in tangent loops serves as a divide-and-conquer strategy to simplify the cognitive challenge of connecting all segments in a continuous line. This intermediate constraint also improves the creative result, by introducing X-junctions that would otherwise not have been drawn. In the final step of my process, the drawings are rendered in wire and displayed as wall sculptures (Fig. 1). Each sculpture uses a single strand of 12-gauge copper wire, which is soldered to itself at X-junctions and finished by applying an antiquing solution that produces a dark bronze patina on both the copper wire and lead solder.

Fig. 2. Conventional caricatures (upper) are converted to sets of closed loops (lower) connected by tangent points (denoted by dots). (© Kevin Burns)
Perception

When examined up close, depth relations are unambiguous at X-junctions rendered in wire. But small differences in depth are not perceived at normal viewing distances, so the wire adds a three-dimensional quality without affecting the ambiguities and associated aesthetics of X-junctions. Audience perceptions depend on whether an X-junction is seen as a crossing or tangent, which in turn depends on the curvatures of lines and the angles between lines and at and near the point of contact.

At a crossing, the four segments meeting at a point are aligned such that two appear to exhibit the Gestalt principle of good continuation in one direction and the other two appear continuous in another direction. The resulting interpretation is that one continuous edge lies in front of the other. But unlike a T-junction, where two segments of one continuous edge appear to occlude another edge, either edge of an X-junction can be perceived as occluding the other, so the surfaces are perceived as transparent with depth relations alternating dynamically between the two interpretations. This is similar to a Necker cube, except that X-junctions formed by curved line segments introduce additional ambiguity as to whether the contact point is a crossing or tangent point.

Multimodal percepts of a different nature occur at X-junctions seen as tangents. In one mode, the two continuous lines appear to be edges bounding surfaces that touch, such that both edges are perceived as having the same depth. In another mode, segments of one edge appear to be occluded by the other edge, so the X-junction is perceived as two T-junctions. This mode is strongest when a discontinuity in one segment is suggested by high curvature at the point of contact. Examples in Fig. 1 include the neck lines of Left and shoulder lines of Right, which appear to be occluded by jaw lines.

Aesthetics

As described above, the production and perception of continuous-line caricatures exploit cognitive constraints associated with X-junctions. These X-junctions are introduced in a systematic fashion, shown in Fig. 2, to achieve an aesthetic effect. This effect is informed by mathematical modeling of Bayesian inference as it applies to human perception [5] and aesthetic evaluation [6,7], including empirical testing [8,9] of a formal theory dubbed EVE’ (Expectation, Violation, Explanation).

According to EVE’, the magnitude of an aesthetic response can be computed as a mathematical product of arousal from surprise, measured by marginal entropy, and appraisal of meaning, measured by posterior probability. The appraisal produces pleasure by resolving the tension of arousal. In a continuous-line caricature, X-junctions induce meaningful surprises when percepts alternate from one probable interpretation to another and back again as the artwork is examined. The result is a feeling of pleasure that comes from “getting” the artist’s “punch lines.”

Importantly, the aesthetic arises not merely from surprise but from surprise resolved by meaning. According to EVE’, both surprise and meaning are needed to achieve the aesthetic effect, and that is the beauty of constrained ambiguity at X-junctions. In constrained ambiguity, several meanings are each much more probable than other meanings. This enables an audience to experience a series of surprises as interpretations oscillate between the probable meanings. The same aesthetic cannot be evoked by unambiguity, where a single meaning is much more probable than other meanings, or by complete ambiguity, with no meaning(s) being much more probable than other meanings.

Extension

Besides enabling the aesthetic described above, another advantage of a continuous-line drawing is that, when start and end points are connected, the result is an Eulerian graph in which an even number of edges meet at each vertex (X-junction). The geometric dual of an Eulerian graph is known to be bipartite [10], so all regions of the drawing can be filled using only two colors (one for each bounded region) such that no region shares a boundary with a region of the same color (except at the points of X-junctions).

In effect, an additional constraint on the production of artworks arises from X-junctions, in the form of a procedure for coloring the regions of a continuous-line drawing and erasing the line itself. I used this constraint to render Left and Right in color woodcut prints (hence mirror reversed) titled Blue and Red (Fig. 3). The continuous line of the original drawing is absent but implied along the boundaries of colored regions. The blue and red colors were chosen to be close in grayscale value, which induces perceptual vibrations at boundaries between regions, not unlike the perceptual oscillations of edges near X-junctions in the original line drawings.

Fig. 3. Blue and Red, diptych, color woodcut prints, 60 × 35 cm, 2018. (© Kevin Burns)

References and Notes