

Spatially-global integration of closed contours by means of shortest-path in a log-polar representation

Terry Kwon, Kunal Agrawal, Yunfeng Li, and Zygmunt Pizlo, Psychology, Purdue University

When the visual information is transmitted from the retina to the area V1, the polar coordinate system on the retina is transformed to a Cartesian coordinate system in V1. More specifically, the distance from the center of the retina (r) is transformed into natural logarithm of this distance ($\ln(r)$). In this transformation, circles centered at the fovea are transformed into horizontal lines in V1. Conversely, smooth horizontal curves in V1 correspond to smooth, convex, closed contours around the fovea (Fig. 1). Finally, the log-polar mapping is conformal, which means that local angles are preserved and are translation invariant (Fig. 1). This allows using definition of smoothness in consistent way across the representation in V1. Our model takes advantage of these geometrical properties. It takes pieces of contours in the image and finds the best curve as the shortest (least-cost) path in the log-polar representation. The results are accurate and computationally easy regardless of the number of distractor (noise) contours. So, the model solves two problems at once: selects the correct subset of contours and decides about how they should be connected. In the psychophysical experiment, the subject was presented with a fragmented polygon (Figure 2a) and asked to draw the polygon they see. The density of the pieces of contour was uniform all over the screen to minimize the role of proximity cue. The orientation of each target contour fragment was randomly perturbed by varying levels of jitter. Higher levels of jitter made the task more difficult. The performance of the model was similar to our subjects'. When the polygon is concave, local interpolation is used as the first operation in the model based on a colinearity criterion. This model cannot be applied to curves that do not contain the fovea in its interior region. We tested subjects in a signal detection experiment with curves (i) around the fixation point or (ii) outside. We set the jitter level to minimize the effectiveness of local interpolation in the visual system. With such stimuli, performance was very good in condition (i) and close to chance level in condition (ii).

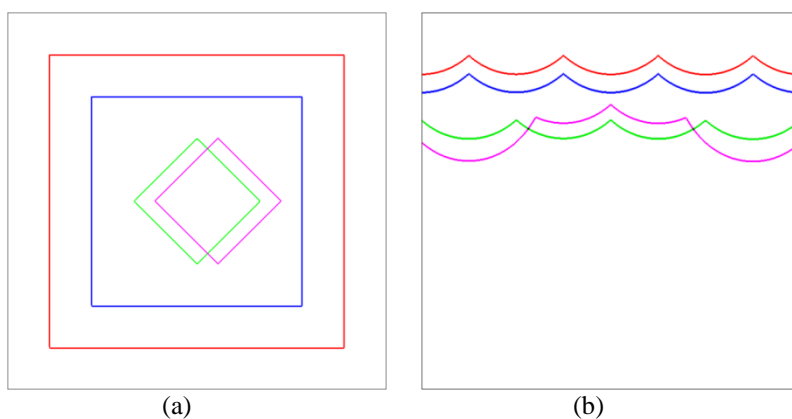


Figure 1. Four squares on the retina (a) are mapped into curves in the log-polar representation of the area V1 (b).

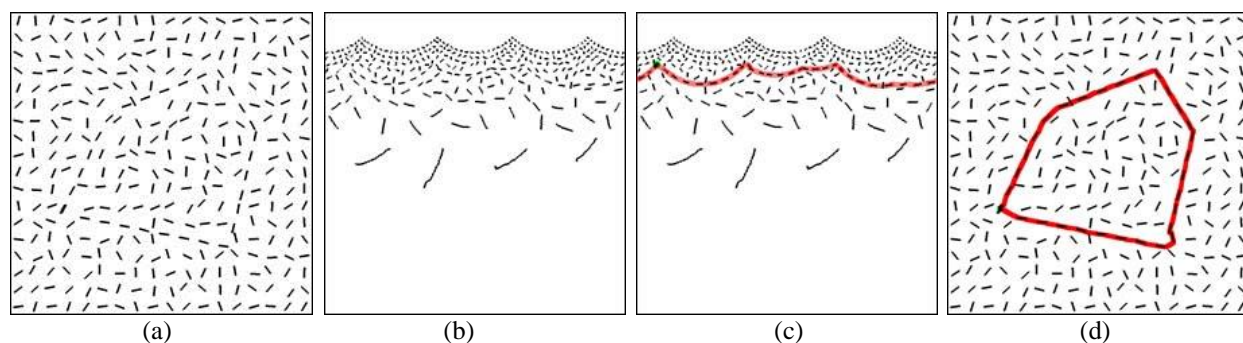


Figure 2. An image (a) is transformed to the log-polar representation (b). The model finds the path shown in (c) that minimized the cost by using a designated starting point. After this path is found, it is transformed back to the image representation (d).