Visualizing Flow Fields by Perceptual Motion

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Abstract

Visualizing flow fields has a wide variety of applications in scientific simulation and computer graphics. Existing approaches either depict a static flow field on a single image, or animate a dynamic flow field through multiple frames. In this paper, we demonstrate a system that attempts to combine the advantages of both. Our approach allows users to perceive flow motion via one single, static image. The system is extremely simple to implement and requires no display computation resources. It can also be deployed on a variety of mediums, including papers.

Keywords: visualization, human perception, texture

1 Summary

Flow field visualization is important for scientific simulation, computer vision, image processing, and computer graphics. A flow field can come from a variety of sources such as turbulence simulation for airplane wings, optical flow from a stereo pair of images, or wind direction measured from weather stations.

Traditional approaches for visualizing a flow field can be classified into two major categories. *Static* methods represent a flow field on a single image, and utilize icons such as arrows or flow lines to convey the motion. *Dynamic* methods animate a flow field by processing it into a sequence of images, such as phase shifting filter [Freeman et al. 1991]. Static methods can be used with passive displays including papers, but they are usually not as effective in conveying the sense of motion. In contrast, dynamic methods usually provide a more lively sense of motion, but they require an active display and consume power and CPU/GPU resources.

We present an alternative that combines the advantages of both. Similar to static methods, our visualization does not require an active display, but at the same time provides a sense of "animation" by exploiting the human visual system. An example visualization is shown in Figure 1. When the image is zoomed in to cover the majority of the field of view, one can notice the circles appear to be moving in similar directions to the input flow field.

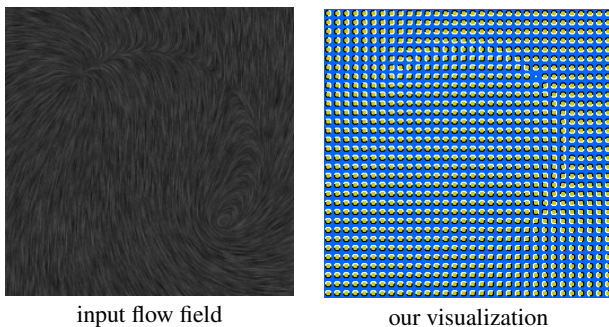input flow field   our visualization

Figure 1: *Visualization by perceptual motion. The input vector field is shown on the left, and our visualization is shown on the right. If the image appears static, please enlarge it on your display.*

Our system is extremely simple to implement. We place yellow circles on a uniform blue background, and surround each circle with a thin layer of border, half in black and half in white. Given this color combination, the circles would appear to move in the direction of black border. To visualize a given flow field, all we need is to orient the circles so that their black border point to the direction of the flow. Examples of other kinds of flow fields are included in the Appendix.

We have not yet found a full psychophysical explanation of this visual phenomenon, but we believe it is related to the high-pass filtering property of rod-receptors in the human visual system [Wandell 1995]. Empirically, the motion is more obvious outside the fovea region, and ceases completely with steady gaze.

In addition, there remains a rich space of parameters we wish to explore. We describe the most important ones below.

Color The colors do not necessarily have to be yellow, blue, black, and white, even though they work very well in our experience. We have experimented with other color combinations, and observed that as long the colors are sufficiently different from each other, the motion would be perceivable.

Distribution The circles can be placed in different distributions. We have found that a simple uniform distribution works well, as shown in Figure 1. A Poisson distribution, in contrast, would often confuse the structure of the motion. We have also found that if the circles are distributed so that they align on the isocontours, the effect would be better sometimes, but this seems to work well only for simple flow fields.

Size and Shape The size of the circles can be changed according to the local strength of the flow, even though the perceived speed of motion does not seem to change accordingly. Also, we don't have to restrict the shape to circles; we have found that other convex shapes, such as ovals, also work well. It would also be desirable to arrange the circles in such way that it reduces to traditional static visualization images when viewers have difficulty perceiving the motion.

Even in this early stage of this project, we are already excited by the potential of this methodology. We believe our system can be applied to other visualizations such as shape and shading, in addition to flow fields. We are also working toward understanding the exact psychophysical reason of the perceived motion, and the explanation should help improve the effectiveness of the visualization. Finally, a major limitation of our approach is that the resolution of the visualization is relatively low compared to pixel-based approaches such as line-integral-convolution, and we are investigating optimizations that could maximize the information density of our technique.
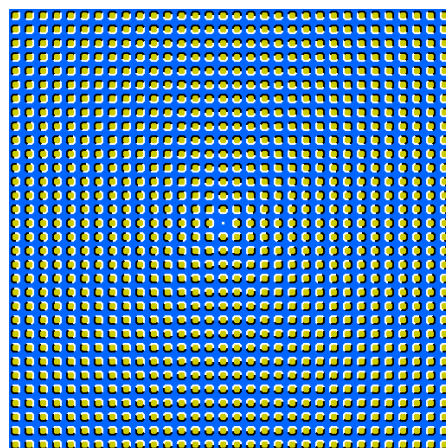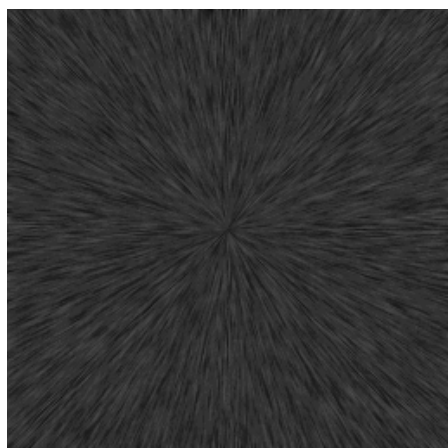
References

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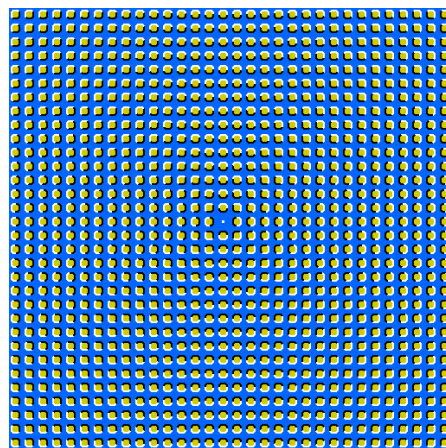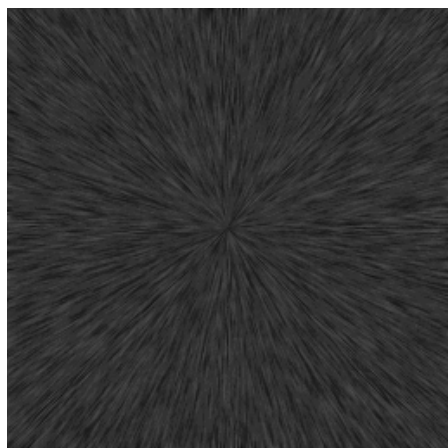WANDELL, B. 1995. *Foundations of Vision: Behavior, Neuroscience and Computation*. Sinauer Associates.
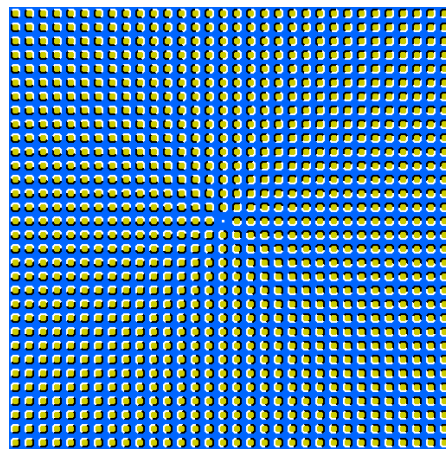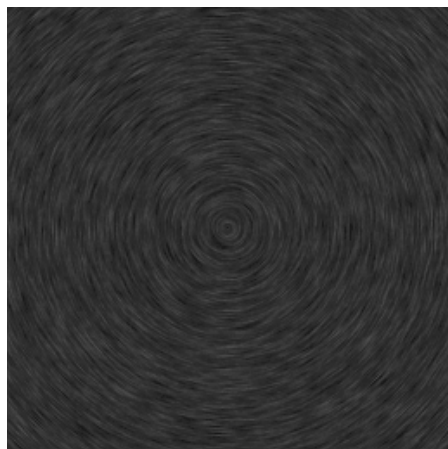
horizontal
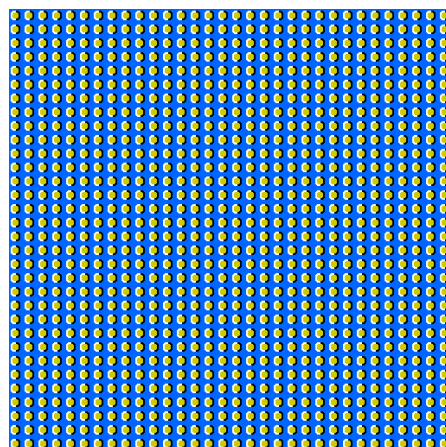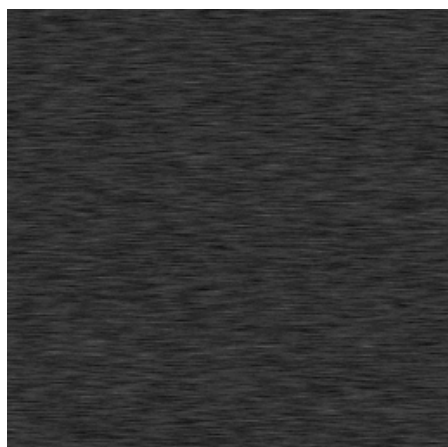
source

sink

vortex

Figure 2: *Visualization of basic flow fields. For each pair of images, the input vector field is shown on the left, and our visualization is shown on the right.*
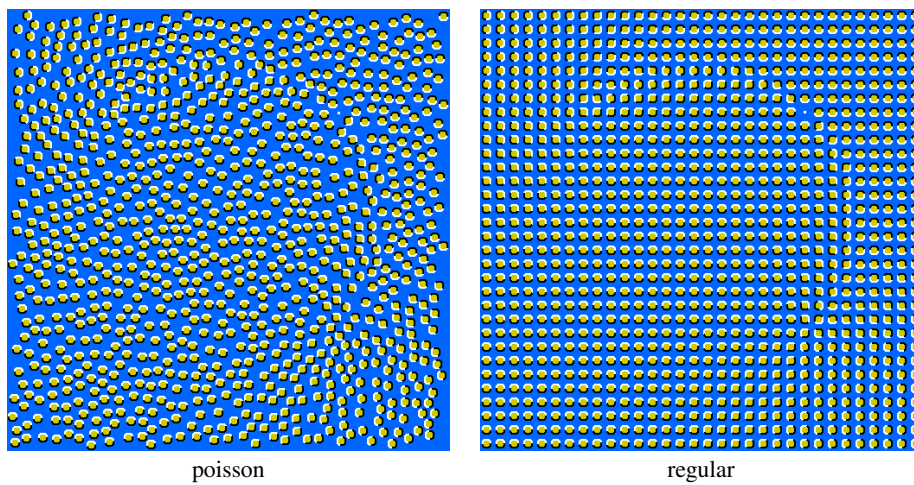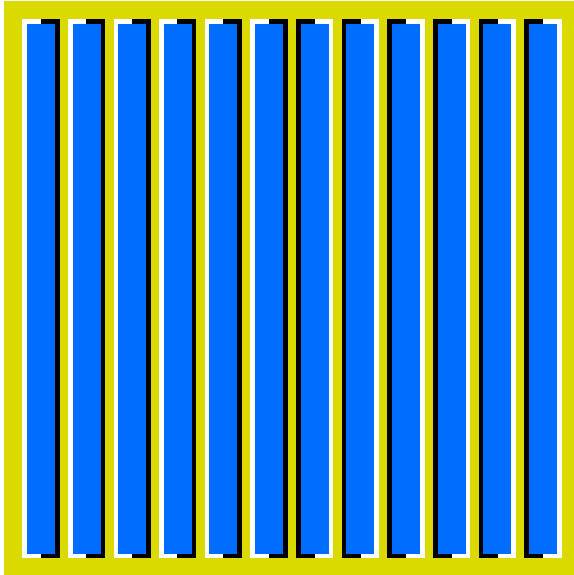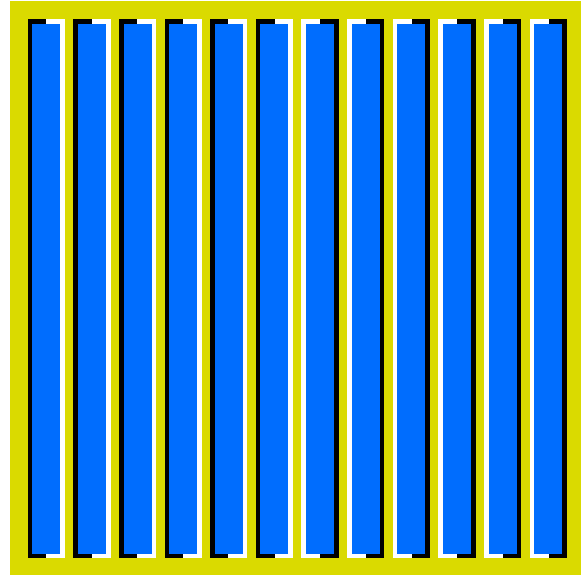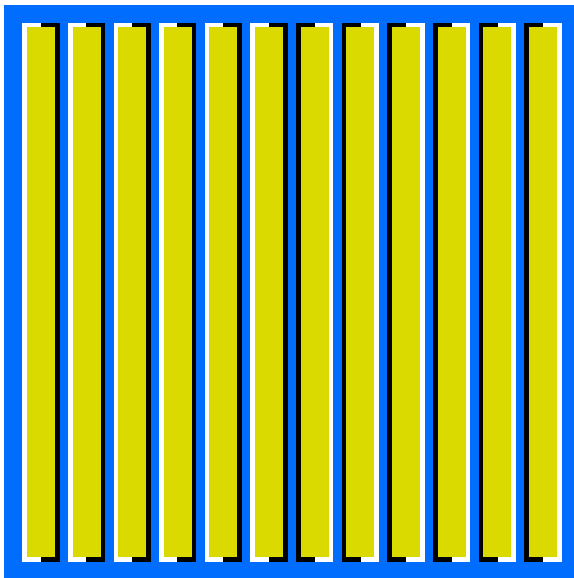
poisson   regular

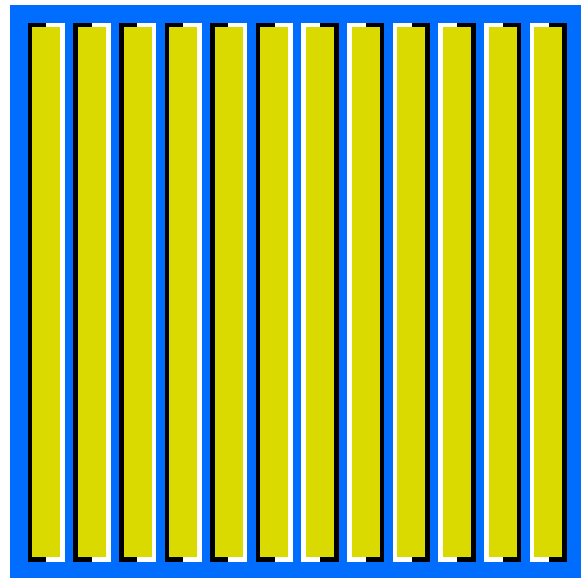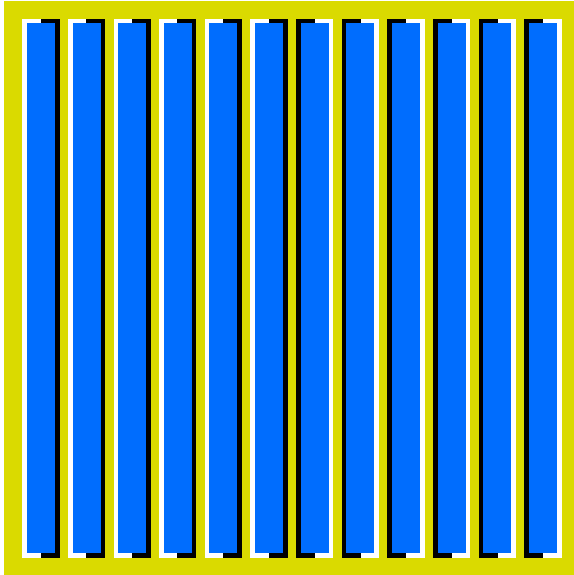Figure 3: *Comparison of poisson and regular distribution.*
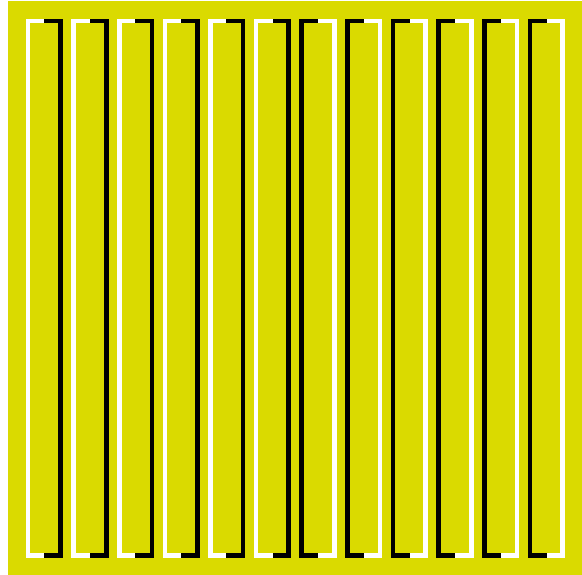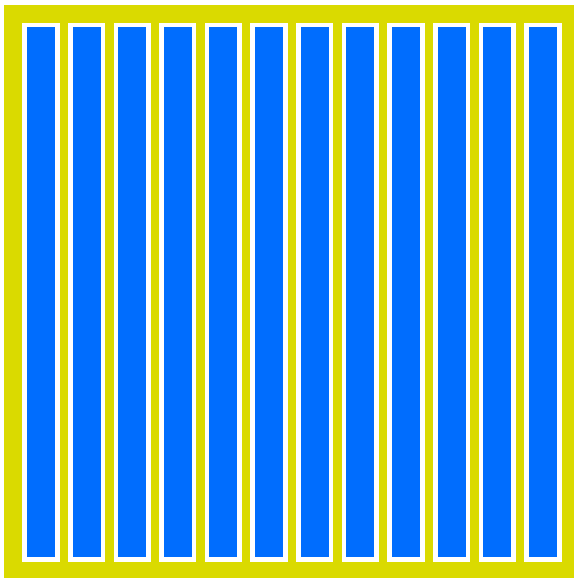
outward

inward

inward

outward

Figure 4: *The direction of perceptual motion depends on the border and content colors.*
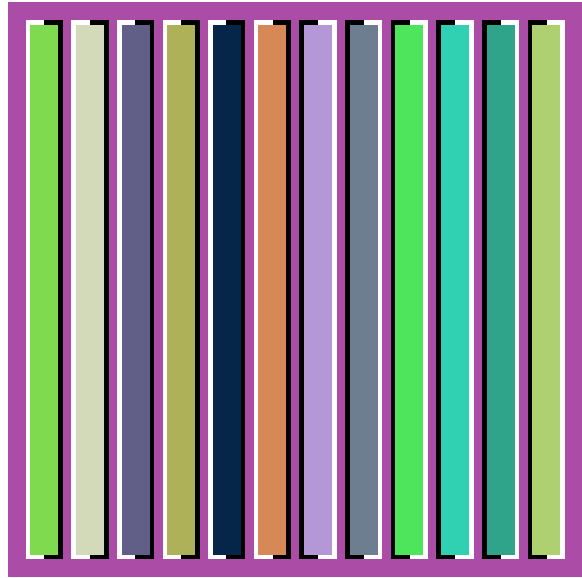
has motion

no motion

no motion

can you see any motion?

Figure 5: *The disappearance of perceptual motion.*