



An Analysis of Moiré Patterns in Halftones

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Introduction

Halftoning is the standard coloring method used in print. A halftone (Figure 1) is a pattern which is made of up to four overlapping grids of dots, each grid being either cyan, magenta, yellow, or black. It is possible for moiré patterns to appear in halftones, depending on how the grids are angled relative to one another (Figure 2). Moiré patterns are interference patterns which appear when two similar patterns are overlaid. Since moiré patterns disturb the quality and consistency of colors in print, it is important that they are kept to a minimum. This project introduces mathematical derivations regarding moiré patterns in halftones, as well as tools which assist in analyzing and predicting these patterns.

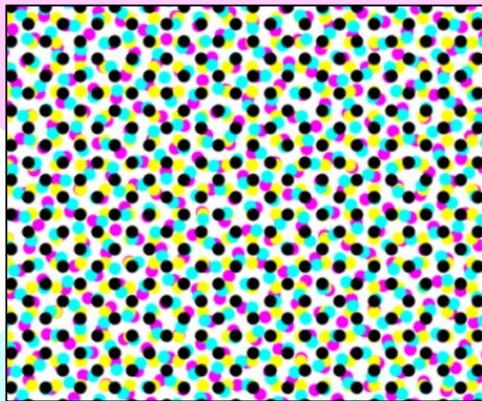


Figure 1: A standard halftone.

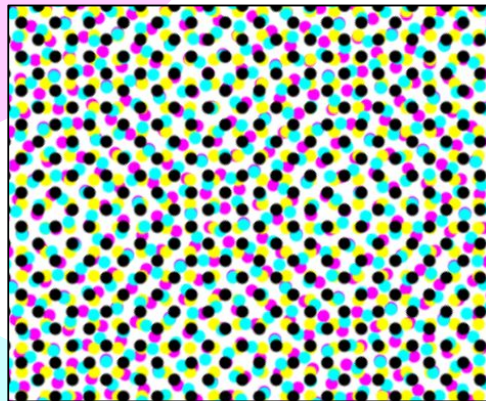


Figure 2: A halftone with a moiré pattern.

Analysis

When two dot grids are overlaid, one with angle V and the other with angle W :

- The resulting moiré pattern looks like another grid of dots.
- The angle of the moiré pattern is the average of V and W .
- If V and W differ by no more than 45° , the distance between each dot in the moiré pattern is equal to the expression shown in Figure 6.

When a third dot grid is overlaid...

- The predictor lines of the three dot grids may themselves create a moiré pattern. This 'superpattern' disrupts the consistency of the halftone in a much larger way than the standard moiré pattern formed by the dot grids. This disruption is most apparent when looking at the Moiré Heatmap. The Analysis Toolkit for this project includes lines that predict these superpatterns. See Figure 7.

When a fourth dot grid is overlaid...

- The resulting moiré pattern is a combination of each moiré pattern formed by all six possible pairs of grids, as well as each superpattern formed by all four possible groups of three grids.

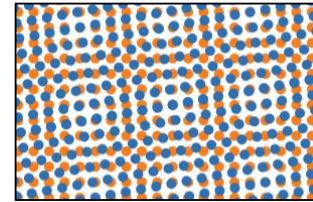


Figure 3: Example of a two-grid halftone in Halftone Playground.

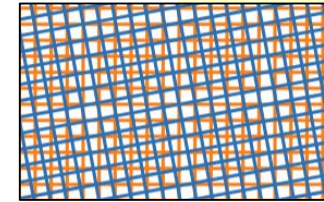


Figure 4: The same halftone, but in Analysis Toolkit.

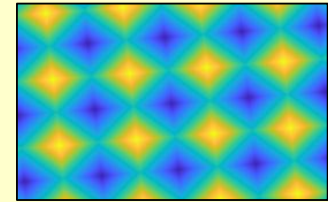


Figure 5: The same halftone, but as a Moiré Heatmap.

Tools

We created three tools that assist in the analysis of moiré patterns in halftones:

1. **Halftone Playground:** A Desmos workspace which allows the user to angle four separate dot grids in whatever way they like. The capabilities of Desmos allow the transitions between angles to be smooth, so the evolution of the moiré pattern is easier to see. See Figure 3.
2. **Analysis Toolkit:** A Desmos workspace in which the dot grids characteristic of halftones are replaced with grids formed by lines. This allows the trigonometry which dictates the appearance of the moiré pattern to be more apparent. 'Predictor lines' which predict the moiré pattern are also included. See Figure 4.
3. **Moiré Heatmap:** A MATLAB script which creates a 3D graph of the halftone, with the z-axis representing how "noisy" the pattern is at a given point. The user can flatten the graph in order to obtain a heatmap, which visually represents the moiré pattern in a way which is consistent with how it actually looks in the halftone. The blue areas indicate where dots in the moiré pattern appear. See Figure 5.

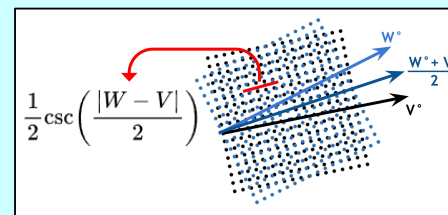


Figure 6: Analysis of a moiré pattern.

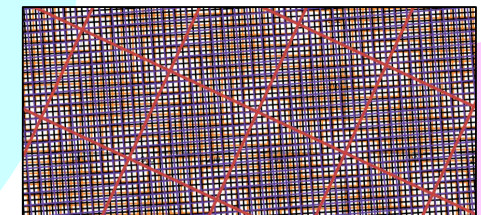


Figure 7: A superpattern, along with its predictor lines.

Conclusion

In order for moiré patterns in halftones to be analyzed, they must first be visualized in an intuitive and interactive manner. Using tools which fulfill this need, it can be seen that they get increasingly more complex with every dot grid that is added. When four grids are overlaid, the resulting moiré pattern is a combination of several overlapping moiré patterns and superpatterns.

This information is key when it comes to minimizing the appearance of moiré patterns in halftones. Yet, there is still much more analysis left to be done on this subject. We plan to publicly release the tools we created for this project, so others can visualize halftones they plan to use, as well as make observations and derivations of their own.