Multi-Image Obscuration within Moiré Patterns

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Motivation and Related Work

The superposition of banding images (alternating black and white stripes, arranged in linear or sinusoidal patterns) often leads to interesting and unique visual effects. One family of superpositions, referred to as Moiré fringe patterns, is the result of interferences between periodic bands. Moiré images have two components: the base band image and the revealing bands. As the revealing mask is translated across a processed image, different amounts of shift will cause obvious visual effects, particularly beating animation.

Moiré image families are described by the function to the right. Here, k is an integer that corresponds to the shifted difference.

$$\frac{\Phi(x,y)}{T_a} - \frac{\Psi(x,y)}{T_b} = k$$

In our application, we use $\Phi(x,y) = Q(x,y)$, where $Q(x,y)$ is the original banded image. We also use $\Psi(x,y) = Q(x,y) - G(x,y)$, where $G(x,y)$ is a pattern or image we wish to obscure. When we substitute these two images into the equation for Moiré image families, we obtain $G(x,y)$ at each integer shift of the base image, k.

$$\frac{Q(x,y)}{T} - \frac{Q(x,y) - G(x,y)}{T} \Rightarrow \frac{G(x,y)}{T} = k$$

By generating a revealing mask image and then offsetting it by an image we want to obscure, we are able to recover the obscured offset by overlaying the revealing mask on the offset image. This leads to some interesting, beautiful, and unique image patterns.

Image Manipulation Methods

To form Moiré band images, we developed a pipeline with multiple adjustable parameters. We can use this pipeline to obscure an image of our choosing and to create variations of the revealing mask. Our process is outlined below:

- We first generate the revealing mask. This is the image that a user will overlay on another image and then translate (either horizontally or vertically) to reveal an embedded image. The band width, angle of grating, and spacing can all be modified to generate a unique mask. Additionally, a geometric transform can be applied to the entire image, like a cosine waveform shift.
- Second, we generate a base band color image using the same parameters as the revealing mask. Since the band period, orientation, and phase all match, all shifts in this base banding will be revealed by the mask.
- We embed our desired image into the base band by shifting each pixel along the y direction by distance proportional to the depth image. No pixel is shifted by more than the period of the banding, to prevent any aliasing when the revealing mask is used. The shift is calculated by the following:

$$y_{new} = y + round(pixelIntensity \times bandPeriod)$$

Our Techniques

Depth Image Estimation

With a black and white image, we apply a series of morphological operations to simulate a depth map, placing emphasis on the foreground. We extract the skeleton of the foreground, calculate the distance transform from the skeleton to the boundary of the shape, and then offset the y pixels in the band image by the depth distance between the foreground and background.

Embedding Depth Images

Our processing pipeline can also obscure depth maps, either rendered out from a precomputed scene or captured with a depth camera. We normalize the depth map and then offset each pixel in the band image by a scaled amount of the depth. When combined with the original band image, the depths are revealed in different colors or greyscale values.

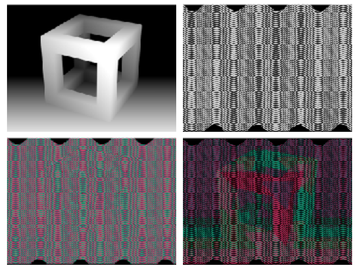
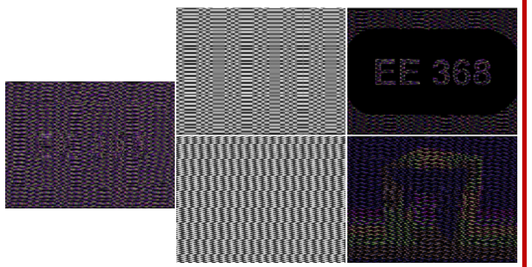


Image Fusion

Combining multiple images into the same band pattern is quite simple. The two images are obscured in different band patterns, to be revealed with two separate revealing masks. An OR operation combines these hidden patterns into the same image. The independent images are revealed when the correct revealing mask is used.



Band Transformations

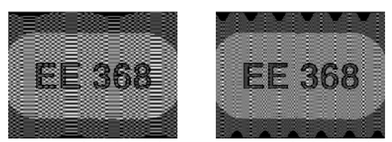
Band Spacing

The banding period is adjustable. Larger band periods result in more levels of depth.

Period = 4px Period = 8px

Band Translations

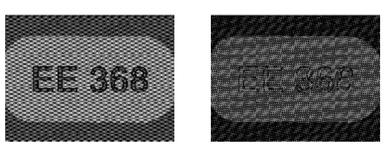
Transforming both bandings by the same parameters still reveals the desired image.



10cos(width/2) 25cos(width/6)

Band Angle

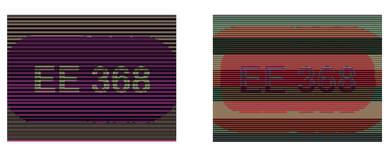
The banding angle is adjustable. Different tilts result in different revealed appearances.



Angle = 10° Angle = 40°

Band Colors

Color replaces the black and white banding, leading to different colors at different depths.



4 Colors 6 Colors

Future Work

The techniques demonstrated in this project can be used in counterfeit prevention measures by banks and treasuries.
One could use a cell phone and camera as the tunable revealing layer, which only works when the parameters are matched. This allows two parties to encode and decode secret messages in simple images.
Additionally, these techniques generate interesting and beautiful visuals. We would like to explore different artistic implementations of these concepts.

References

Chosson, Sylvain M., and Roger D. Hersch. "Beating shapes relying on moiré level lines." ACM Transactions on Graphics (TOG) 34.1 (2014): 9.
Hersch, Roger David, and Sylvain Chosson. "Band moiré images." ACM Transactions on Graphics (TOG). Vol. 23. No. 3. ACM, 2004.
Amidror, Isaac, et al. The theory of the moiré phenomenon. No. LSP-BOOK-2000-001. Dordrecht; Boston: Kluwer Academic, 2000.