Interactive Additive Diffraction Synthesis

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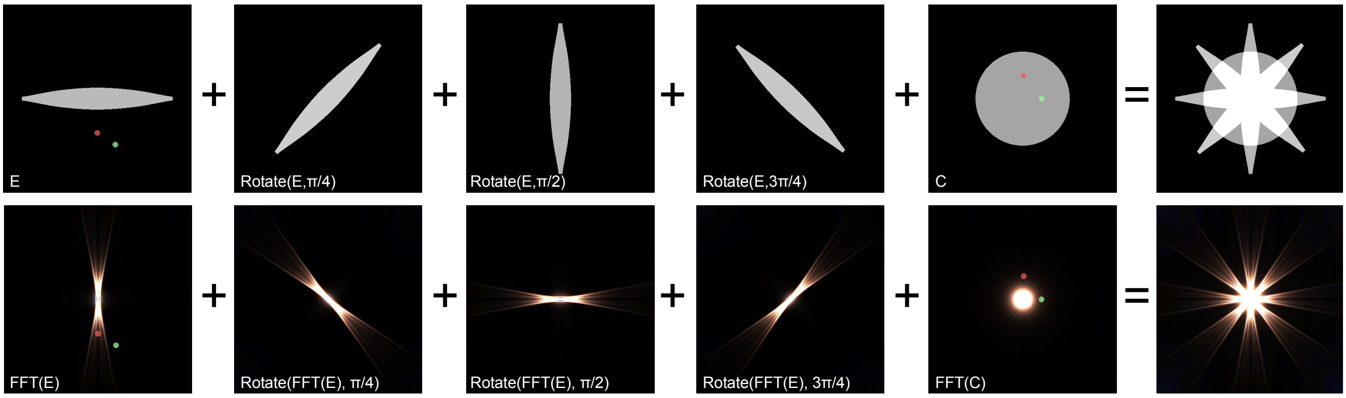

Figure 1: *A realistic diffraction can be synthesized by additively integrating fast Fourier transforms of abstract geometric elements of an aperture and their rotations. Curved blades (E) and circular core (C) abstract non-symmetric streaks and core highlights, respectively. Further, our interaction scheme using two control points (red for intensity and green for tension) allows us to intuitively edit diffraction patterns.*

Abstract

Lens flare, comprising diffraction patterns of direct lights and ghosts of an aperture, is one of artistic artifacts in optical systems. The generation of far-field diffraction patterns has commonly used Fourier transform of the iris apertures. While such outcomes are physically faithful, more flexible and intuitive editing of diffraction patterns has not been explored so far. In this poster, we present a novel scheme of diffraction synthesis, which additively integrates diffraction elements. We decompose the apertures into curved edges and circular core so that they abstract non-symmetric streaks and circular core highlights, respectively. We then apply Fourier transform for each, rotate them, and finally composite them into a single output image. In this way, we can easily generate diffraction patterns similarly to that of the source aperture and more exaggerated ones, as well.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Display algorithms

1. Introduction and Background

Lens flare, comprising *diffraction* patterns of direct lights and *ghosts* of an aperture, is one of artistic artifacts in optical systems. It indicates the presence and direction of light sources, and gives aesthetic atmosphere, resulting in further realism to photographic imagery. In particular, starburst patterns, caused by diffraction at the aperture of the optical system, strongly affect the shape of the diffraction.

Fraunhofer approximation of diffractions can be interpreted as Fourier transform (FT) [PW15]. Many previous studies used fast FT (FFT) to produce physically faithful glare images. Early approaches included pupils and eyelashes of human eyes, and rendered diffraction images using FFT with wave optics [KMN*04, RIF*09]. Later extensions constructed photographic lens systems to render lens flares and ghosts [HESL11, LE13]. They have shown physically-based accurate appearances of lens flares, but their diffraction patterns have been limited in fixed forms.

Since the previous approaches commonly used regular aperture geometries (often augmented with noises) to produce diffraction patterns, their application to expressive scenarios has been limited. A common problem is that the shape of the aperture indirectly relates to the shape of diffraction by FT. This makes hard to expect the

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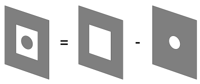

Figure 2: *A complex aperture and its diffraction can be broken up to simple apertures and addition/subtraction of their diffractions [PW15].*

resulting pattern of a complex aperture in advance. Classical physics identified that FT of the complex aperture is equivalent to the addition/subtraction of those of individual geometric elements [PW15] (see Figure 2). This physical background inspired us to explore more intuitive and easier way to edit diffraction patterns by extracting atomic geometric elements and applying FT to them, separately.

This poster presents a novel scheme of diffraction synthesis, which additively integrates diffraction elements. Since edges of apertures are most pronounced in its diffraction, we decompose apertures into curved edges and circular core to abstract non-symmetric streaks and a circular highlights, respectively. We then apply FFT for each, rotate them, and finally composite them into a single output image. For dispersion, we further apply repeated scaling and integration over different visible wavelengths similarly to the previous work [KMN*04, RIF*09]. Our user interface supports intuitive interaction using two control points, which can be often useful for achieving apparent atmosphere and exaggeration (see Figure 1).

Ours makes a distinction from the previous ones in two aspects. First, ours can instantly re-generate a diffraction of a different number of blades without re-computing its FT; this is useful for low-performance (e.g., mobile) devices. Second, it is easier to add per-blade details than the whole-aperture FT (e.g., by generating single-blade diffractions with different noises and deformations).

2. Diffraction Synthesis

Starburst patterns of diffractions are closely related to the shape of the source aperture. In the aperture, light scatters at the edges of the aperture (blades), and the resulting patterns resemble the starburst (see Figure 3a). Convex or concave edges (having stronger tensions) make the diffracted streaks broader (Figures 3b and 3c).

Unlike the previous straightforward approach (taking directly FT of the input aperture), we extract key geometric features of the aperture based on our observation. We take only the (curved) edges (see Figure 3d and 3e) and use double-sided curved edges as an atomic aperture element. For instance, a virtual aperture with three thick lines (Figure 3d) yields similar patterns to that from a hexagonal aperture (Figure 3a); however, their intensities may differ.

The symmetric circular core of diffraction pattern has broader highlights, which commonly appears for all the aperture shapes. We abstract the highlight using a circular element. By controlling the intensity and size of this circle, we can emphasize the core highlights.

A user can interact with each diffraction element using two (red and green) control points. The red point commonly controls intensity (using the distance to the screen center) and rotation. The green point controls the tension of the curves—this is equivalent to the widths of streaks—and the oval distortion of the circle, respectively.

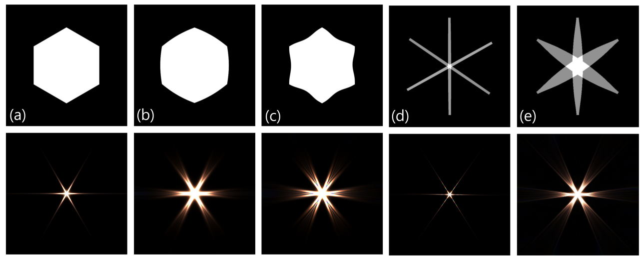

Figure 3: *Regular apertures (a, b, and c) and our abstract apertures (d and e) shown in the upper row produce similar diffraction patterns (lower row).*

3. Results and Discussions

We implemented our solution using OpenGL on an Intel i7 3.60 GHz CPU and NVIDIA GTX980 Ti at 1024×1024 resolution. The current formulation requires to apply FFT twice, one for the blade and the other for the circle. After compositing them and their rotations (as many as the number of polygonal edges) into a single image, we accumulate scaled copies of the initial output to reflect the dispersion of different wavelengths. Performance of the whole synthesis and rendering take roughly 5.1 ms. Such lightweight computation is appropriate for real-time user editing with instant feedback.

Our work is preliminary, and has potentials of creating expressive diffraction patterns including non-symmetric and irregular patterns. We plan to extend the current work for a more complete solution.

One of the limitations is that our aperture is non-physical and cannot be directly used for ghost generation (crucial for complete lens flares). Associating intuitive elements and their diffractions with realistic apertures will be a good direction for future work.

Acknowledgments

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