Diffraction Based Image Synthesis

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Abstract. In this paper, we explore the analysis of optical lens systems by using diffraction-based image synthesis. The resolution and strong contrast are the major characteristics of the image produced from the high-quality optical lens system. To check the image's quality using the PSF, Image Simulation (IMS) method with a fast Fourier transform convolution algorithm. The Strehl ratio is a measure of the quality of optical image formation from the imaging system. It is well-defined as the ratio of peak focal irradiance to the diffraction-limited peak irradiance. The image quality assessment is done by code V up to scent percentage if the image quality is too good and the Strehl ratio is more. Image quality is worse than the Strehl ratio percentage is low. Finally compute with the sample optical lens system Strehl ratio between automatic optical lens design Strehl ratios in Code V.

Keywords: IMS, PSF, Optical lens system, FFT, Code V.

1. Introduction

The system indicates the capturing object from the optical system (camera). An optical lens system or imaging system nowadays performed various tasks such as inspection analysis and measurement [2]. Such systems' dependability relies upon various variables, including a light source, scene geometrical properties, scattering properties of the surfaces, and the optics' nature. A mix of these components, in the end, affects the subsequent image and prompts some vulnerability in the end measurement [15]. The process of imaging formulation and it is hard to assess the optical lens system's quality without taking original images and impossible to conduct experiment setup all other optical system conditions for all individual optical lens systems [16]. Accordingly, Code V simulation could check all-optical lens system conditions for all individual model designs.

The major resolution limit [12] and diffraction effects of assuming a significant function that operates in an optical lens system simulation for more in the coherent imaging, and diffraction prompts to the creation of an abstraction called as speckle [4], which impacts the measurements of vulnerability [5]. Diffraction influences the resolution from the incoherent optical lens system [6]. Such impacts are either not expressible by diffraction optics/others, for example, abnormalities or blurring computational ways to deal with the ray tracing. Figure 1 discusses about Capturing object from the optical system.
Figure 1: Capturing object from the optical system (Camera).

Here uses automatic optical lens system design to formulate image from the object, often simulating an imaging system [7]. The optical lens system consisting of three steps to the formation of the image from the object are light transmission on the object, optical imaging system, and conversion from object to image [8]. In this main simulation contribution from the last steps for that process called post-processing, to verify the image in the Strehl ratio of the sample lens system [9] and demonstrate the automatic optic lens design with its PSF of Strehl ratio, which describes the quality of image and image simulation (IMS) which shows the performance of the image resolution and contrast of the image [10].

*Process of image formation*

Figure 2: Schematic image formation process.

The Figure 2 shows the how the image formation from the object using a light source via an optical imaging system. The steps taken for image creation in the optical lens system (Imaging system) in this section are
section 2.1 describes the light source transport on image and how ray tracing works using light on the object, and section 2.2 Imaging optics describes the aperture integration and optical effects.

1.1 The light source transport on image

The light source transport is that describes the equilibrium distribution of radiance in an object. It gives the all-out reflected brilliance at a point on a surface and its BSDF, the approximation of occurrence brightening showing up the point. We will proceed with considering the situation where there are no partaking media in the scene.

The detail that makes assessing the light transform is difficult, i.e., how incident radiance at a point is influenced by the geometry and scattering properties of the object. A splendid (bright) light gleaming on a red object may cause patterns on a tabletop. Delivering algorithms representing this complex nature are regularly called global illumination algorithms to separate from this local illumination algorithm that utilizes just data about the local surface properties in their shading computation.

In this section, the light source transport assessment on the image is fascinating with a high-level theory. There are having promptly accessible truly based renders, for example, mitsuba[11], giving admittance to numerous valuable rendering models. Hence, the simulating process's number of steps can be completed using computer graphic techniques to assess the object accurately. The below sections are focused more on the image formation process method.

1.2 Optical lens system

An ideal (optical) imaging system is to center got light source that enters the aperture originating from one place into another place on the object. Actually, in case this planning isn't ideal and anticipates deviation from an ideal image brought from the distortion, out-off focus affects aperture diffraction and so on some proposal’s deviation been effectively reviewed in a ray of tracing structures by including focal points and its base to the ray tracing [8] other wonders like diffraction of aperture only sensible by signals direct of light has similarly reproduced in a beam-based way [14]. The genuine focal points for adequately impersonating such impacts can reduce the delivery productivity and augment the delivery time [1]. The coherent light is brought obstruction pattern, and it can't be rehashed in such way and expected some different techniques [2] otherwise committing optical lens techniques [2].

Optical imaging lens systems quickly examine the combination of source light on the aperture and propose utilizing wavelength filtering technique from FF optics to present optical lens system phenomena brought about from focal point and aperture [3].

I am propagating light Source over the aperture: The shared objective of ordinary way ray of tracing algorithm use to affectively appraise object radiance \( L_s \) from a point \( P \) to the relating source pint \( X_p \) with the principal ray of coordinates as a through an ideal pin- opening camera imaging the object.

As shown in the below Figure 3, the real approaching propagates from the object to the imaging place leads to the co-ordination of propagating values from the aperture upon subtended strong inclination \( \omega \). In CG, Monto Carlo examines the need to test positions on other objects and the aperture. This is, in fact, conceivable, none the focal point with the development of the conveying time.

In an optical lens systems situation, the scene's separation to this lens allowed gap is significantly bigger than the lens gap diameter. Hence, the strong point prescribed by the optical system is smaller. Particularly if the surface is preferably diffuse over specula, we can inexact the object propagates to be practically uniform upon the entire solid inclination \( \omega \) with this supposition the propagating gathered by the gap of lens given as below equation [15]

\[
I_{rr}(X_p) = \frac{\pi}{4} \left( \frac{D}{f} \right)^2 \cos^4 \theta L_s(X_p) \tag{1}
\]
Where $f$ is compared to the imaging system's focal length, and $D$ indicates the aperture diameter.

**Figure 3:** The real approach is propagating from the object to the imaged.

*Simulation of optical lens system effects by FF Optics:* In Fast Fourier optics, an optical imaging lens system is demonstrated as a linear imaging system with PSF [10]. The meaning of the linear optical system is that it may hang on upon the unity of the light source. If the illumination is incoherent and the i/p power is $I^\text{in}$.

Hence the yield power $I^\text{out}$ for incoherent optical lens system is given by convolution with the incoherent Point Spread Function $h_i$.

$$I^\text{out} = I^\text{in} * h_i$$  \hfill (2)

The framework isn't any more straight on the info powers yet rather acts directly on the impacts signal field $E_{in}$ and then convolves with the coherent Point spread function $h_c$

$$E^\text{out}_c = E^\text{in}_c * h_c$$  \hfill (3)

For effectively reproducing obstruction, which shows up the incoherent optical system, the input wave in the deciding factor for the phase input signal on the off chance that phase set for the entire wavefield (for the most part zero stage) coherent image formation lessens to the incase of incoherent. At the point, whether light is dissipated by a lens that is harsh in frequency, the phase factor is thought will be freely consistently conveyed in $(\theta, 2\pi)$ [17]. The point spread spectrum incoherent optical lens system can lead to exceptionally nonlinear effects for the yield power as assumed in equation (5). The nonlinear diffraction effects for a laser source light show give speckles.

$$I^\text{out}_c = \left[\left(\sqrt{I^\text{in}_c e^{iE}}\right) * h_c\right]^2$$  \hfill (4)

Where $I^\text{out}_c$ is coherent output intensity, $I^\text{in}_c$ incoherent intensity, and $h_c$ PSF.

Computationally, it is more helpful to translate this ordinary perspective into the comparable one in the recurrence space. The FFT of $h_c$ is known as ATF. In case of incoherence FT of $h_i$ is indicated by OTF. Its
ray demonstrated that the Optical transfer function is the standardized function of correlation in the
amplitude transfer function [10].

For the two plans, the \( I_n \) term can be given by an optical imaging system anticipated by graphical
delivering strategies on a fundamental level knowing specific ATF extra optical lens system can be
acquainted with the simulated image by handling stage.

We generally can appraise the framework move work, and along these optical impacts will resemble
savvy guess. In the beam following stage, it is basic to screen sound and ambiguous light segments on the
item and brief an unpredictable phase of the cognizant beams that show up at the goal, resulting in being
scattered by an unforgiving surface. Rational and indistinguishable picture fragments must be diversely
separated and a while later included.

**Diffraction limited optical lens systems:** The optical framework opening forces an essential resolution limit
on the optical lens system Rayleigh limit [11]. If other lens system facts, for example, noises are not
predominant, and the imaging object has a good resolution than Rayleigh limit effectively the system is
known to be diffraction-limited also works at (or near) this resolution limit, for this situation, the amplitude
transfer function or Optical transfer function of aperture diffraction is sufficient to show the entire imaging
objective which can be determined assumed the aperture size, the shape also other distance to the object, for
example, the ATF of a rounded aperture with diameter \( D \) and distance to the object is given by

\[
H(m_x, m_y) = \text{circ} \left( 2\pi \left| \frac{m_x^2 + m_y^2}{D} \right| \right)
\]

(5)

Where \((m_x, m_y)\) indicates the 2D frequency components, and \( D \) is the circular aperture diameter.

\( \text{circ}(Y) = (1, \quad \text{for } |Y| \leq 10, \quad \text{otherwise}) \)

2. **IMS Model**

Image simulation (IMS) shows a "real" graphical object as imaged by the optical system. The object file
should be. The BMP file used to make an image has pixel-based simulations such as 640X450, 1024X1200,
and the object diagonal is mapped to the specified FOV (field of view); therefore, inappropriately sized can
cause several warning and error message when using IMS.

IMS includes the analysis like diffraction, which convolves with the field- varying PSF, distortion, image
orientations, vignetting and other transmission variations, axial and lateral color.

At the end, it computes an array of PSF's from the optical system that is convolved with the input object's
pixels, as shown below Figure 4.

The PSF's are either polychromatic or separate PSF's for R, G, B bands and distortion determined from
the chief ray trace. Convolution we need a PSF for every pixel in the image and some intermediate pixels
(which is usually most of them) nearby PSF's are interpolated to synthesize intermediate PSF's and thus
PSF's are traced at field defined by PMX/PMY, which is calculated set of array size with "number of samples
in X/Y.

IMS computes multiple PSF's and accuracy using appropriate computations parameters TGR, NRD, and
GRI. FFT grid size (TGR) is the total number of rays across the transform grid in both X. The total number
of rays across the transform grid in both X and Y. The nature of rays across the diameter (NRD) is the
number of rays across the pupil diameter, and Focal plane increment (GRI) is the spacing between samples
in the image plane. The IMS is useful for visualizing and communicating abstract matrices, and its accuracy
depends on correct PSF input, and it's available as an alternative to NRD/GRI.
Figure 4: An array of PSF's from the optical system that is convolved with the input object's pixels.

Figure 5: Flow diagram of diffraction-based image synthesis.

The IMS algorithm, as shown in the above Figure 5 and it has computed the five steps as below as follows.

**Step 1:** let us consider input as an object for the optical imaging system.

**Step 2:** The automatic optical lens system design receives the input object from the diffraction image simulation input object.

**Step 3:** The automatic optical lens system produces the PSF and convolves with the input image.

**Step 4:** convolution process output receives the output of the convolution between input images between PSF.

**Step 5:** Image simulation receives the convolution output, and it gives an inverted image of the input object, and the output has a good Strehl ratio.

3. **IMS Result Analysis with an Optical Lens System**

Image simulation is used to shows the appearance of a real graphical as imaged by using an optical lens system (imaging system), and it is analysis the optical system based on diffraction, which convolves with varying PSF.

The Strehl ratio is a ratio of the quality of optical image formation from the imaging system. It is well-defined as the ratio of peak focal irradiance to the diffraction-limited peak irradiance. The image quality assessment is done by code V up to scent percentage [18]. If the image quality is too good and the percentage of the Strehl ratio increases, image quality is worse than the Strehl ratio percentage. Table 1 shows the optical lens system's sample and automated designed optical system with a good Strehl ratio of quality of the image. The PSF of all three fields describes the peak intensity of the image and produces the Strehl ratio.
Computer simulation between the outputs Strehl ratio of sample optical lens system and automated optical lens design and IMS produces the best Strehl ratio of the automated optical lens is 0.893446.

Table 1: Result in an analysis of image simulation.

| Optical Lens system | Strehl ratio |
|---------------------|--------------|
| Input object        | 0.459546     |
| Output image        | 0.893446     |
|                     |              |
4. Conclusion
This paper confirms that the automatic optical lens design techniques can produce a good Strehl ratio, which indicates that the image's quality includes high resolution and contrast. Code V is used to vary the optical lens design of surface parameters for image simulation. IMS uses Fast Fourier Transform convolution with each pixel PSF with the input image, and it produces an inverted image that is too high-quality or high Strehl ratio. It's concluded with computing with the sample optical lens system Strehl ratio between automatic optical lenses designs Strehl ratios in Code V. Therefore, it gives the best "State of Art."

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