Attenuation-based Light Field Displays

Bachelorarbeit

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Abstract

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Capturing a Light Field

2.1 The Plenoptic Function and the Light Field

The plenoptic function, as introduced by [AB91], is a 7D function that describes the intensity of light for every frequency, along every light ray in space, at any time. It is defined as

$$\begin{aligned} P\colon \mathbb{R}^3 \times [0, 2\pi) \times [0, \pi] \times \mathbb{R}^2 &\to \mathbb{R}^+ \\ (x, y, z, \theta, \phi, t, \lambda) &\mapsto P\,(x, y, z, \theta, \phi, t, \lambda)\,, \end{aligned}$$

where the parameters (x, y, z) are the coordinates of a point in 3D space and the angles (θ, ϕ) describe the direction of an incoming light ray at time t. The light's intensity is given for every wavelength λ and thus, the plenoptic function not only captures the visible frequency spectrum but all electromagnetic waves. A commonly used measure for light is the radiance, which is obtained from P by integrating over all wavelengths: $R\,(x, y, z, \theta, \phi, t) = \int_{\mathbb{R}} P\,(x, y, z, \theta, \phi, t, \lambda)\;\mathrm{d}\lambda$.

In practice, it is impossible to acquire all the data needed to model the 7D plenoptic function and hence it is reasonable to consider only a subset of the parameters. Dropping the time parameter t in $R\,(x, y, z, \theta, \phi, t)$ yields a 5D function for the radiance in a static scene. As described by [LH96], this five dimensional representation can further be reduced to four dimensions in the following way. The radiance along a line is constant in free space and so, the 5D plenoptic function holds redundant information for the points on this line. Ignoring this redundancy leads to the equivalent 4D parameterization of the ray space. [LH96] propose a parameterization by two parallel planes, as seen in figure 2.1, where the coordinates of the lines (rays) are given by the intersections with the two planes. The **4D light field** $L(u, v, s, t)$ is therefore defined as the radiance along the line intersecting the two planes at coordinates (u, v) and (s, t). This two plane parameterization of the light field is the most common one seen in literature, but there are many ways to choose a parameterization. For instance, one can use a plane and two angles to define each ray passing this plane, which would result in a light field $L(u, v, \theta, \phi)$ where $\theta, \phi \in (0, \pi)$.

2.2 Light Field Acquisition

For practical applications, the light field must be discretized and so an appropriate sampling method needs to be chosen. One way is to capture the light field with a grid of optical systems, e.g. cameras. Typically, the (u, v)-plane is uniformly sampled on a grid $G_{uv} = \{(u_i, v_j) \mid i = 1, \ldots, n, j = 1, \ldots, m\}$ on the (u, v)-plane with a resolution $n \times m$. The extent in horizontal (vertical) direction is called the horizontal (vertical) **baseline**. This means that only a slice of the actual light field can be captured and the two planes are clipped to form a rectangle.

Oblique Projection

Oblique projection, as shown in figure 2.2(a), is a special case of orthographic projection: The parallel rays do not need to be perpendicular to the image plane of the camera. The advantage is that there is a one-to-one correspondence between camera position and ray angle, since all rays in one camera are parallel. This means that the angular resolution is simply the number of cameras, and the spatial resolution is the number of pixels in the image plane. Given a light field $L(u, v, s, t)$ and the distance d between the two planes, a re-parameterization $L'(\theta, \phi, s, t)$ can be obtained according to figure 2.2(b) by the transformation

$$\theta = \arctan\left(\frac{u-s}{d}\right), \qquad \phi = \arctan\left(\frac{v-t}{d}\right).$$

However, this type of projection is only applicable for synthetic scenes that are rendered with a computer.

Perspective Projection

The angles of the rays in a light field captured by perspective projections are determined by the focal length and the sensor resolution of the camera. For a camera light field, typically it is expected that

- All cameras are placed at grid positions in G_{uv} on the same plane, called the (u, v)-plane,
- The optical axes of the cameras are parallel to the (u, v)-plane,
- All cameras have the same intrinsic parameters (e.g. focal length).

In this case, the focal planes of all cameras coincide with a common focal plane, the (s, t)-plane. Figure 2.3(a) shows this scenario for three cameras in two dimensions.

2.3 Light Field Tomography

2.4 Spectral Analysis

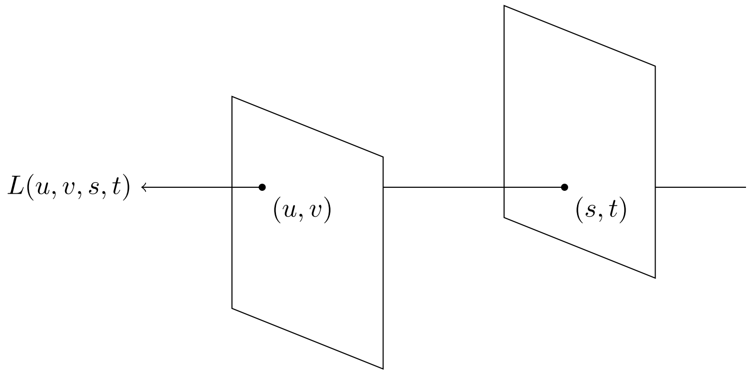

Figure 2.1: Parametrization of the light field with two planes.

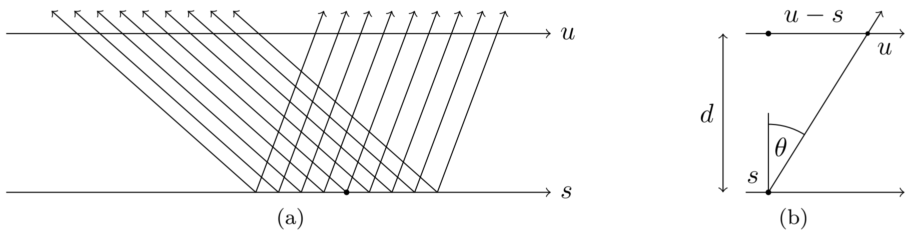

Figure 2.2: (a) Light field aquisition using oblique projection. (b) Re-parameterization of the two-plane representation to angular coordinates.

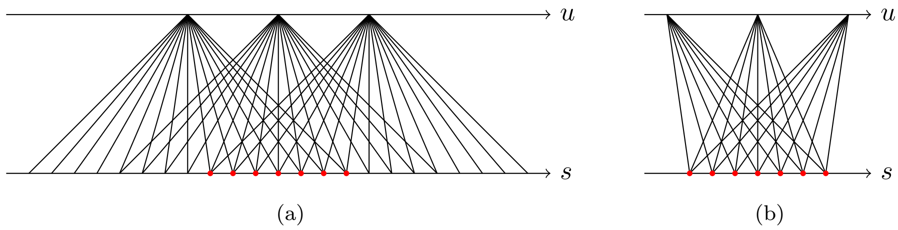

Figure 2.3: Perspective projections of a scene. (a) Shifted Projection (b) Sheared projection.

Appendix A

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A.1 apsec1

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Bibliography

[AB91] ADELSON, E. H. ; BERGEN, J.: The Plenoptic Function and the Elements of Early Vision. In: *Computational Models of Visual Processing* (1991), S. 3–20

[LH96] LEVOY, M. ; HANRAHAN, P.: Light Field Rendering. (1996), S. 1–12

[WLHR11] WETZSTEIN, G. ; LANMAN, D. ; HEIDRICH, W. ; RASKAR, R.: Layered 3D: Tomographic Image Synthesis for Attenuation-based Light Field and High Dynamic Range Displays. In: *ACM Trans. Graph.* 30 (2011), Nr. 4

[WLHR12] WETZSTEIN, G. ; LANMAN, D. ; HIRSCH, M. ; RASKAR, R.: Tensor Displays: Compressive Light Field Synthesis using Multilayer Displays with Directional Backlighting. In: *ACM Trans. Graph. (Proc. SIGGRAPH)* 31 (2012), Nr. 4, S. 1–11

[Yan10] YAN, Ming: Convergence Analysis of SART by Bregman Iteration and Dual Gradient Descent. (2010), S. 1–15

Erklärung

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