Introduction to Computer Vision

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Image Formation

Physical parameters of image formation:

- Optical: focal length, field of view, aperture

- Geometric: types of projection

- Photometric: type, direction, intensity of light reaching the sensor

What is an image?

Until now, an image was defined as a 2D pattern of intensity values. Now, we interpret it as a 2D projection of 3D points. A camera is a device that allows for the projection of points from 3D to 2D. In the process of taking a picture, we preserve things like straight lines and points of incidence, but lose information such as angles and length.

The brightness of an image pixel is determined by the light source, the surface shape, orientation, and reflectance properties, the optics, exposure, and nature of the sensor lens.

Types of 3D Projections

A 3D projection is any method of mapping three-dimensional points to a two-dimensional plane.

- Perspective projections: objects in the distance appear smaller than those close by, and parallel lines converge at a image point in infinity, on the horizon.

- Weak perspective projections: perspective effects, but not over the scale of individual objects.

- Orthographic projections: objects in the distance appear the same as those close by, parallel lengths at all points are of the same scale regardless of the distance of the camera.

In order to perform transformations, we convert to homogeneous coordinates:

$$(x, y) \Rightarrow \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

$$(x, y, z) \Rightarrow \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Projection is a matrix multiplication using these coordinates:

$$\begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} fx \\ fy \\ z \end{bmatrix} \Rightarrow (f\frac{x}{z}, f\frac{y}{z})$$

Vanishing Points

Each set of parallel lines meets at a different point. Sets of parallel lines on the same plane lead to collinear vanishing points. This is a good way to spot faked images since scale and perspective don't work and vanishing points behave badly.

Photometry

The brightness of a pixel is a function of the brightness of the surface in the scene that projects to the pixel. It is dependent on how much light is incident on the surface and the fraction of incident light that gets reflected.

When light hits a point on an object, some of the light gets absorbed, some is transmitted through the object, and some gets reflected. For simplicity, we will assume that surfaces don't fluoresce or emit light, and that all the light leaving a point is due to light arriving at that point.

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Reflection

Modes of reflection:

1. Specular reflection: pure mirror, the incoming ray, outgoing ray, and the normal are coplanar, and the angle of incidence is equal to the angle of reflection.

2. Diffuse reflection: light leaves in equal amounts in each direction so the surface looks equally bright from each viewing direction. Diffuse reflection is described by a parameter called **albedo**, which describes the percentage of light arriving that leaves.

Lambert's Law

$$B = \rho(N \cdot S) = \rho \|S\| \cos \theta$$

where B is the radiosity (total power leaving the surface per unit area), ρ is the albedo (fraction of incident irradiance reflected by the surface), N is the unit normal, and S is the source vector where the magnitude is proportional to the intensity of the source.

Shadows

Most shadows are dark because shadow points get light from other surfaces and not just the light source. Area sources are large bright areas such as the sky which yield smooth blurry shadows.

- Points that can see the whole source are brighter.

- Points that can only see part of the source are darker (penumbra).

- Points that can see no part of the source are darkest (umbra).

Other surfaces can behave light area sources.

You can find all my notes at `http://omgimanerd.tech/notes`. If you have any questions, comments, or concerns, please contact me at alvin@omgimanerd.tech