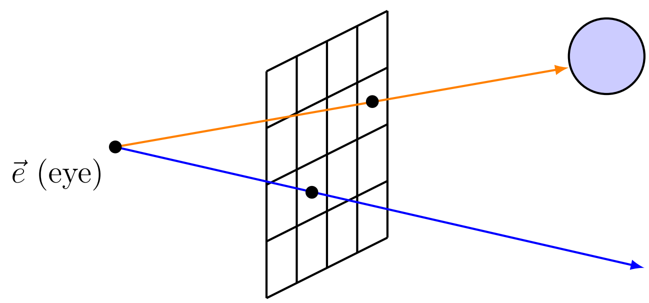
Ray Tracing Overview: Algorithms and Ray Generation

1 Ray Tracing Logic



The following describes the core routine for shading a ray and the top-level loop for image generation.

1.1 Main Render Loop

The process is repeated for every pixel in the target image.

- **For each pixel:**
  - Compute ray r.
  - color = shade-ray(r).
  - Store color in image pixel.

1.2 Shading Routine

The function `shade-ray(r)` determines the color for a given ray r.

intersect-ray(r) $\rightarrow (obj, t)$ {Find the nearest intersection}
if no intersection **then**
  return background-shader(r)
else
  $n =$ normal(obj, x) {Compute normal at intersection point x}
  $c =$ shade(obj, x, n) {Compute color}
  return c
end if

2 Intersection Algorithm

The `intersect-ray(r)` function iterates through objects to find the closest hit.

- Initialize $\hat{t} = \infty$ and $\hat{o} = \emptyset$.
- **For each object** o**:**
  - If o intersects r at distance t:
  - If $t < \hat{t}$:
    - $\hat{t} = t$
    - $\hat{o} = o$
- **Return** $(\hat{o}, \hat{t})$.

3 Ray Generation and Image Space

3.1 Image Plane Geometry

The image is defined by a viewport with boundaries (r_{min}, s_{min}) and (r_{max}, s_{max}). The pixel dimensions are n_x by n_y. For a pixel (i, j), where $0 \leq i < n_x$ and $0 \leq j < n_y$:

- Basis vectors: $||\vec{u}|| = 1$, $||\vec{v}|| = 1$, and $\vec{u} \cdot \vec{v} = 0$.
- Viewport point: $\vec{z} = \vec{p} + r\vec{u} + s\vec{v}$.
- Viewport Area: $(r_{max} - r_{min}) \times (s_{max} - s_{min})$.

3.2 Pixel to World Mapping

To find the world-space coordinate r for a pixel index i, we use a linear mapping $r = ai + b$.

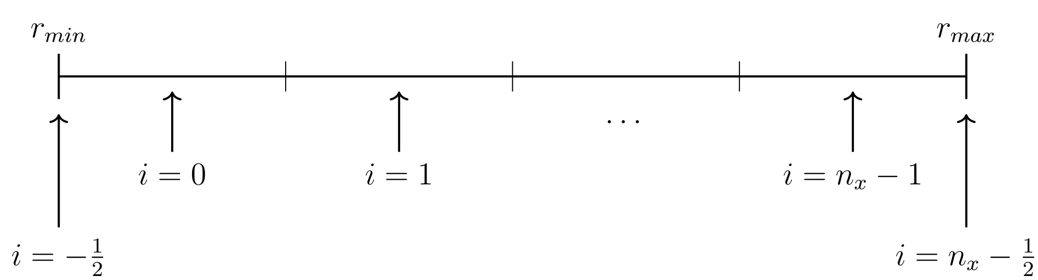


Figure 1: Mapping pixel indices to the viewport range r_{min} to r_{max}.

The boundaries are defined at the half-pixel marks:

$$r_{min} = a\left(-\frac{1}{2}\right) + b \tag{1}$$

$$r_{max} = a\left(n_x - \frac{1}{2}\right) + b \tag{2}$$

Solving for a and b:

$$a = \frac{r_{max} - r_{min}}{n_x} \tag{3}$$

$$b = r_{min} + \frac{a}{2} \tag{4}$$

Resulting in the formula for r:

$$r = \frac{r_{max} - r_{min}}{n_x}\left(i + \frac{1}{2}\right) + r_{min} \tag{5}$$

Mapping for $j \to s$ is performed similarly.

3.3 Final Ray Definition

The ray is defined by its origin $\vec{e}$ and direction $\vec{d}$:

- Direction: $\vec{d} = \frac{\vec{z}-\vec{e}}{||\vec{z}-\vec{e}||}$
- Ray equation: $f(t) = \vec{e} + t\vec{d}$, for $t \geq 0$