Aliasing

Aliasing refers to the visual artifacts or distortions that occur when a high-resolution image or scene is sampled at a lower resolution. It is caused by the **undersampling** of the image, which results in jagged edges or "stair-step" patterns, especially on diagonal or curved lines.

Causes of Aliasing

- Insufficient sampling of the scene.
- Sharp transitions in pixel intensity or color.
- High-frequency content (e.g., fine patterns, small text, or thin lines) being inadequately represented.

Examples of Aliasing

1. **Jagged Edges**: Straight lines at an angle appear as a staircase of pixels instead of smooth lines.
2. **Moiré Patterns**: Repetitive patterns (e.g., grids or textures) create wavy interference effects.
3. **Pixelation**: Low-resolution images appear blocky when displayed at larger sizes.

Anti-Aliasing

Anti-Aliasing is a technique used to minimize or eliminate the effects of aliasing by smoothing out jagged edges and reducing visual distortions. It works by **blending colors** at the boundaries of objects or by increasing the sampling resolution.

How Anti-Aliasing Works

1. **Supersampling (SSAA)**:
    - Render the scene at a higher resolution and then downsample to the desired resolution.
    - This increases the number of samples per pixel, producing smoother edges but at a higher computational cost.
2. **Multisample Anti-Aliasing (MSAA)**:
    - Samples multiple points within each pixel and averages the color values.
    - It focuses on edges, making it more efficient than supersampling.
3. **Post-Processing Techniques**:
    - **FXAA (Fast Approximate Anti-Aliasing)**:

        - Applies anti-aliasing as a post-processing step, analyzing the image for edges and blurring them slightly.
        - Fast and lightweight, but can cause blurring in fine details.
    - **TAA (Temporal Anti-Aliasing)**:
        - Combines information from previous frames to smooth out edges over time.
        - Effective for dynamic scenes but may introduce ghosting.
4. **Smoothing Filters**:
    - Apply a blur or interpolation filter to soften the transitions between pixels.

Examples of Anti-Aliasing in Practice

1. **Text Rendering**:
    - Anti-aliased fonts have smoother edges compared to aliased fonts, improving readability.
2. **3D Games**:
    - Anti-aliasing smooths out jagged edges on objects, enhancing visual quality.

Comparison of Aliasing and Anti-Aliasing

Aspect	Aliasing	Anti-Aliasing
Cause	Insufficient sampling of high-frequency content.	Techniques to smooth or eliminate artifacts.
Visual Effect	Jagged edges, moiré patterns, and pixelation.	Smooth edges and reduced visual distortions.
Implementation	Occurs naturally during rendering.	Requires additional computation or filtering.
Performance	Fast but produces poor quality.	Improves quality but can be computationally expensive.

Illustrative Example

Imagine drawing a diagonal line on a grid of pixels:

- **Aliased Line**: Appears jagged as pixels form a staircase pattern.

- **Anti-Aliased Line**: Appears smooth because intermediate shades are added along the edges, blending the line with its background.
