Computer Graphics

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Wrap up from last week

- **Modeling**
  - **3D Reconstruction**
  - **Solid modeling**
  - **Curve and Surface modeling**

Anti-aliasing

Super-sampling

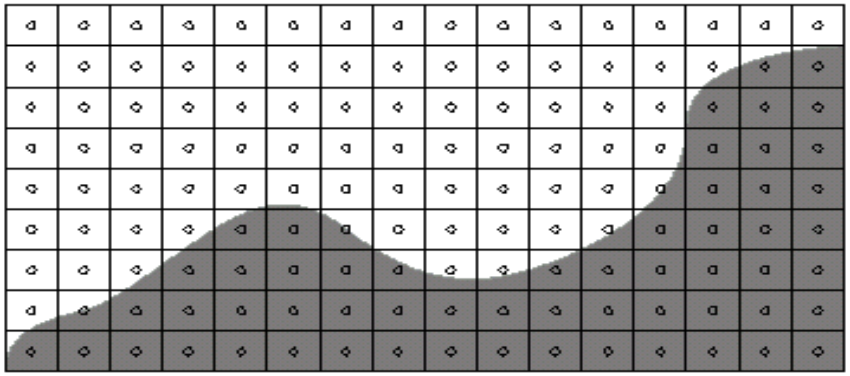
Multi-sampling

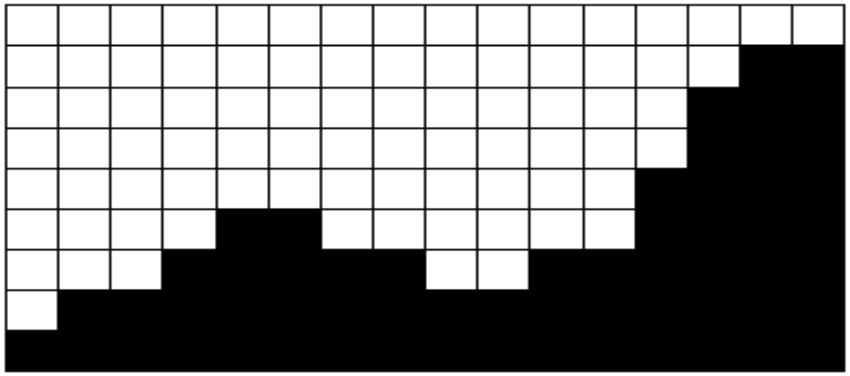
Post Processing

What is Anti-Aliasing

What is Aliasing

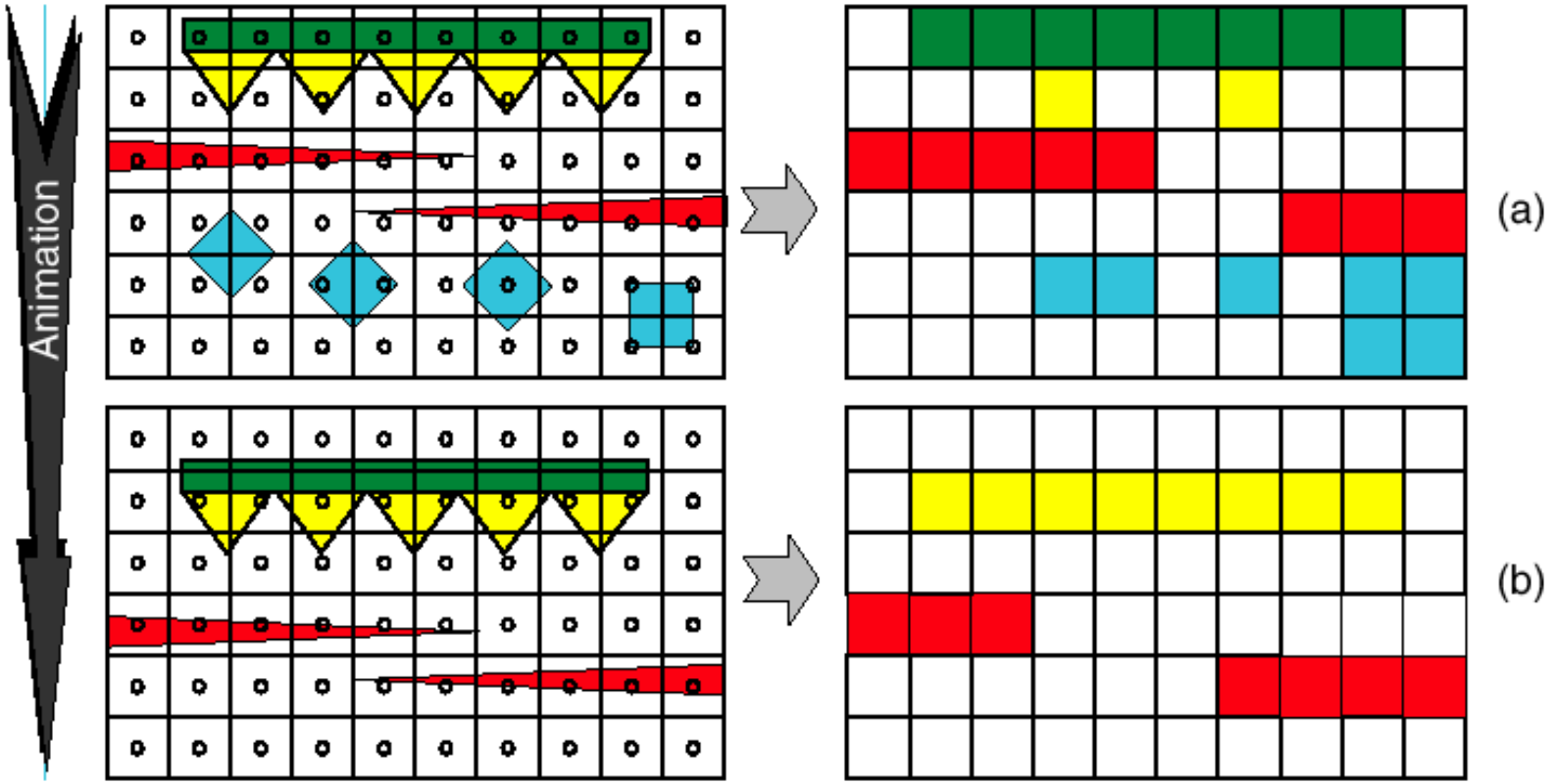
- Staircase-edges (jaggies)





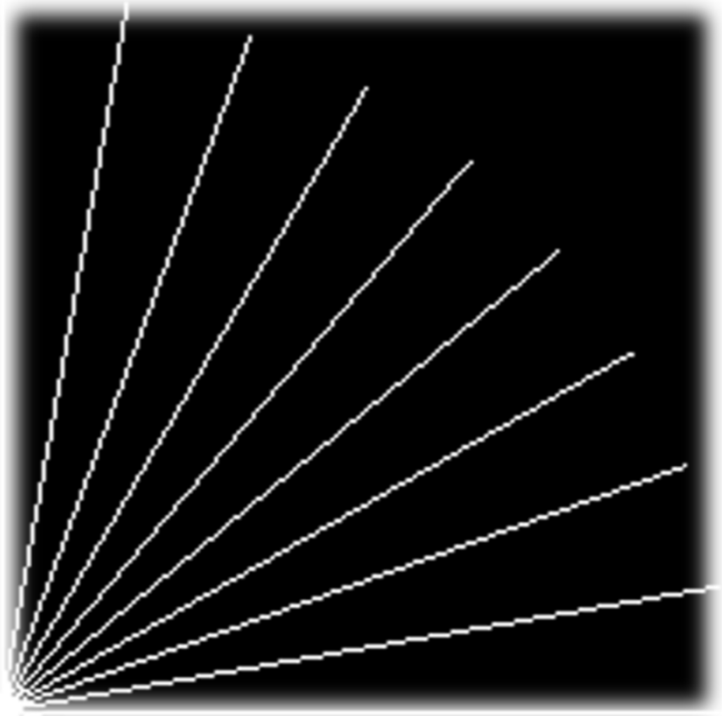
What is Aliasing

- Polygon Poping

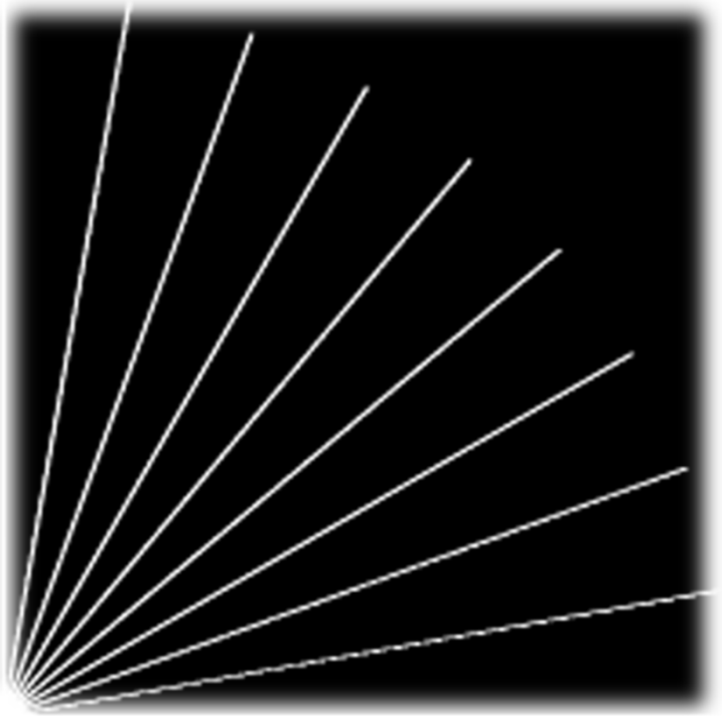


Major Issues

- Smooth the jaggies along the edges



Aliased lines



Anti-aliased lines

Major Issues

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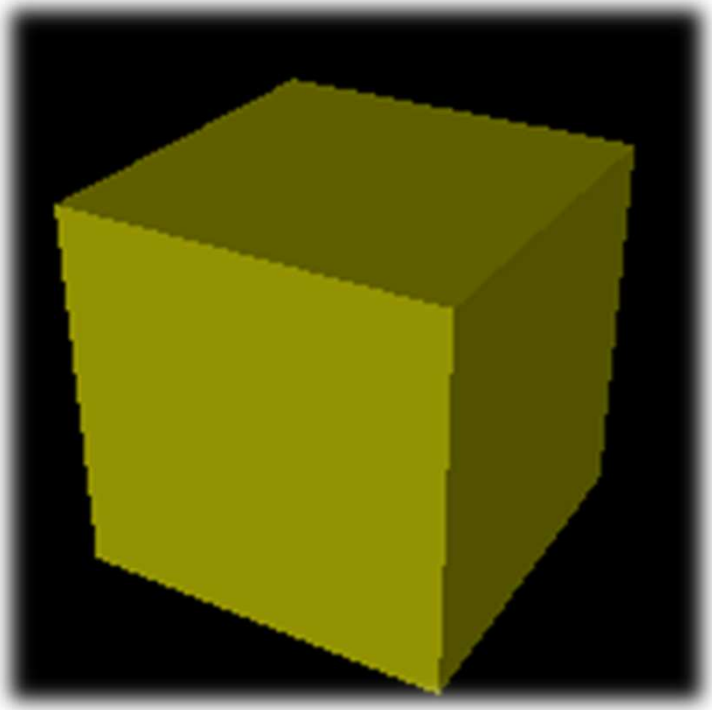
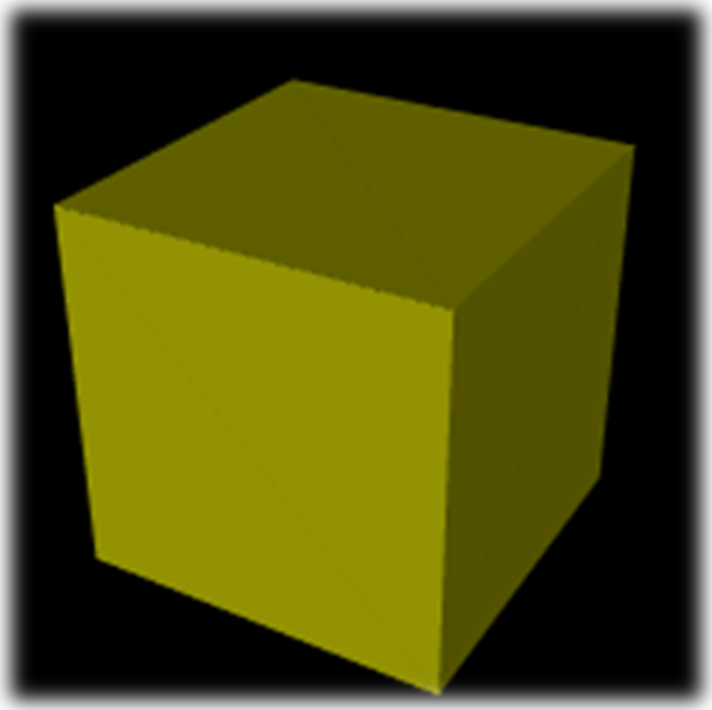


Aliased triangles



Anti-aliased triangles

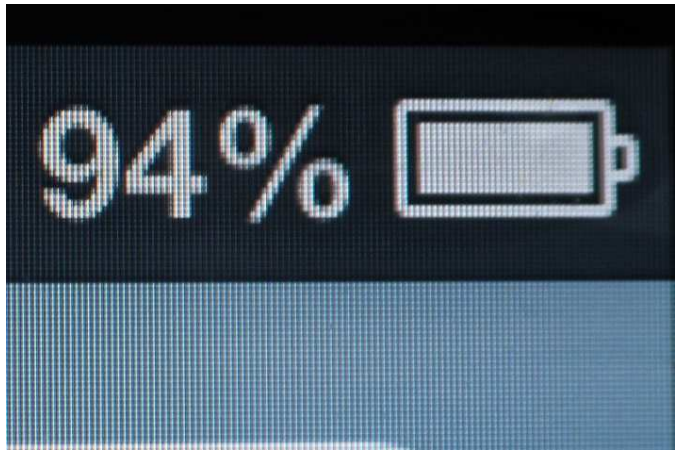
Why Anti-Aliasing ?

- Not enough samples in computer-generated image, results in:
  - Jagged, crawling edge
  - Polygon popping, flickering
- Human eyes are sensitive to discontinuity
- Anti-Aliasing is required for better image quality

Why Anti-Aliasing ?

- **Fake resolution**
  - **Look smooth using anti-aliasing technique under lower resolution**
- **Higher resolution**
  - **Greater than 200ppi (pixel per inch)**
  - **Apple Retina Display (eg. 1440x900 → 2880x1800)**

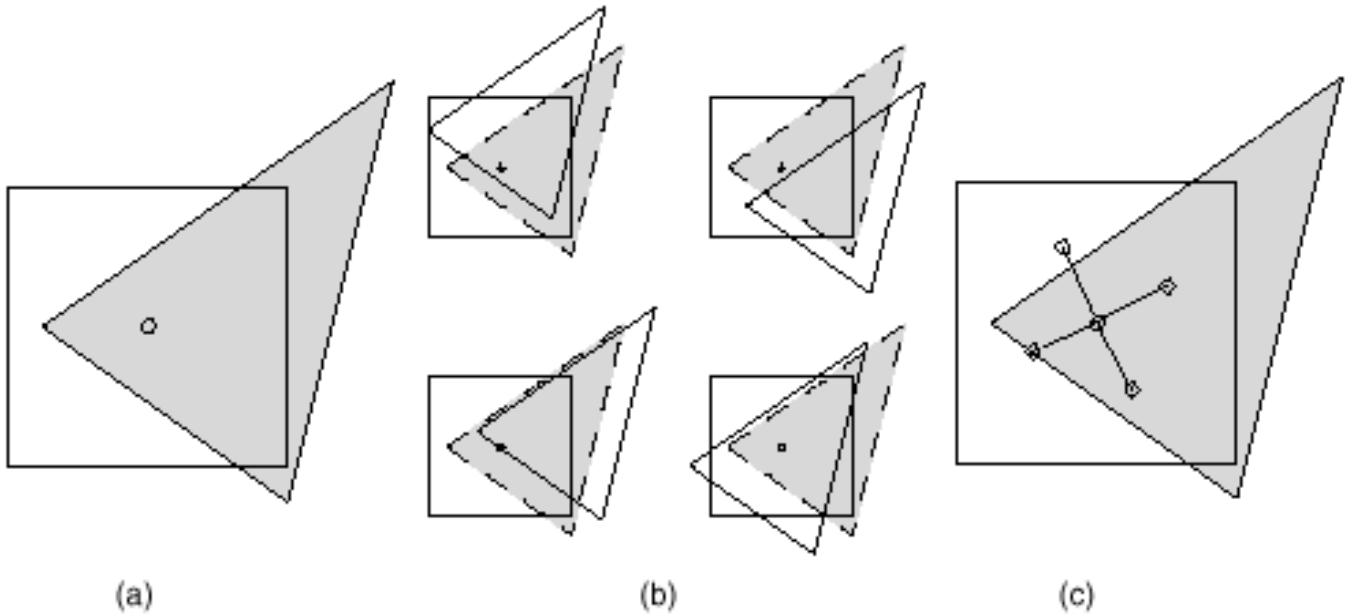
Conventional LCD Display



Retina Display

Accumulation Buffer

- Using jittering technique to draw jittered triangle into different buffers and then accumulate the buffer by some weighting into the final display buffer.



Super-Sampling

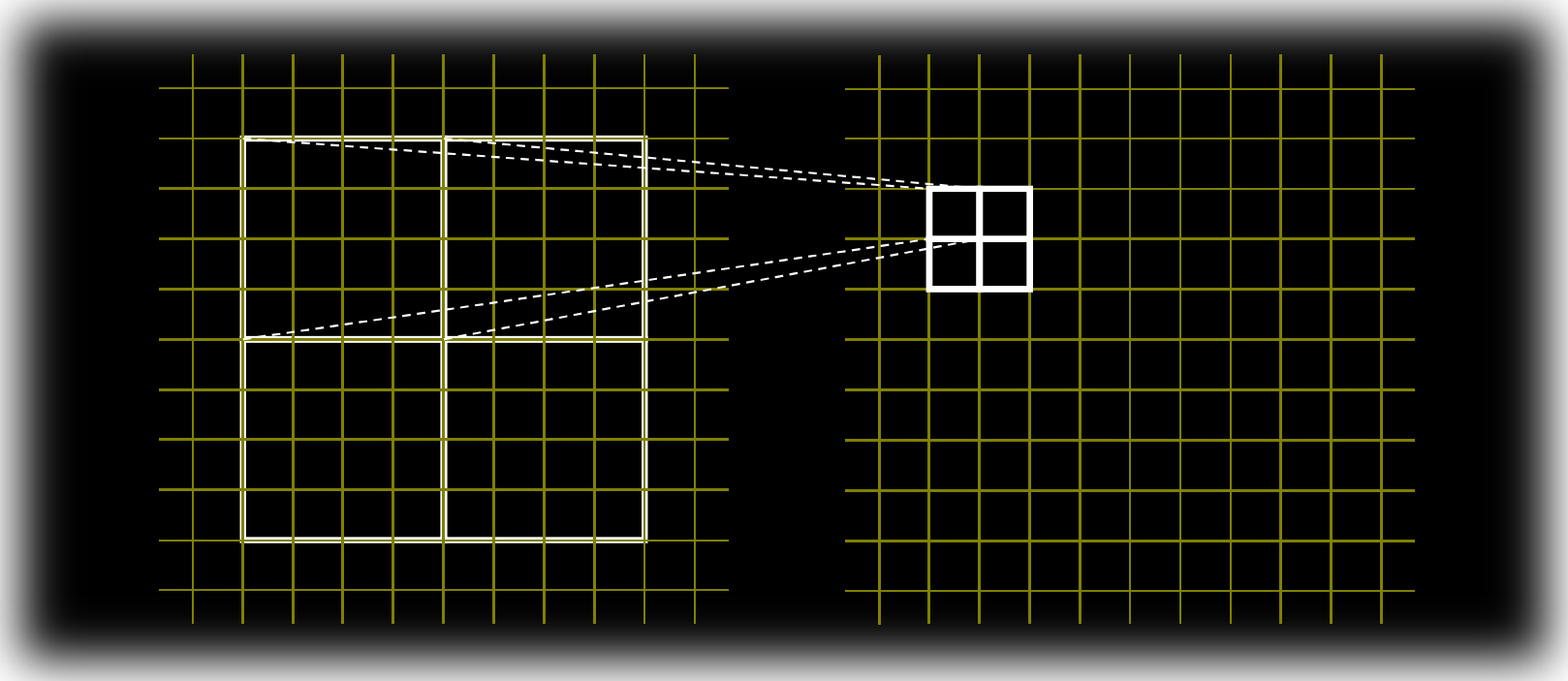
- How to solve aliasing
  - Taking more samples
  - Extra samples instead of one single central sample per-pixel
  - Increase the density of image information
- Two types of super-sampling anti-aliasing
  - Ordered Grid Super-Sampling
  - Rotated Grid Super-Sampling

Super-Sampling

- **Advantage**
  - **Transparent to the user**
  - **Can handle correctly with interpenetrating objects**
- **Disadvantage**
  - **Need more memory to store data**
  - **Need more memory bandwidth to read/write Z and color data**
  - **Longer rasterization time**

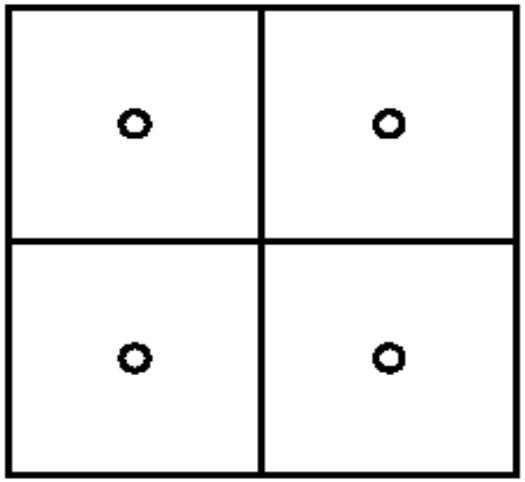
Super-Sampling

- Use more samples per screen grid cell, and blend with assigned weights



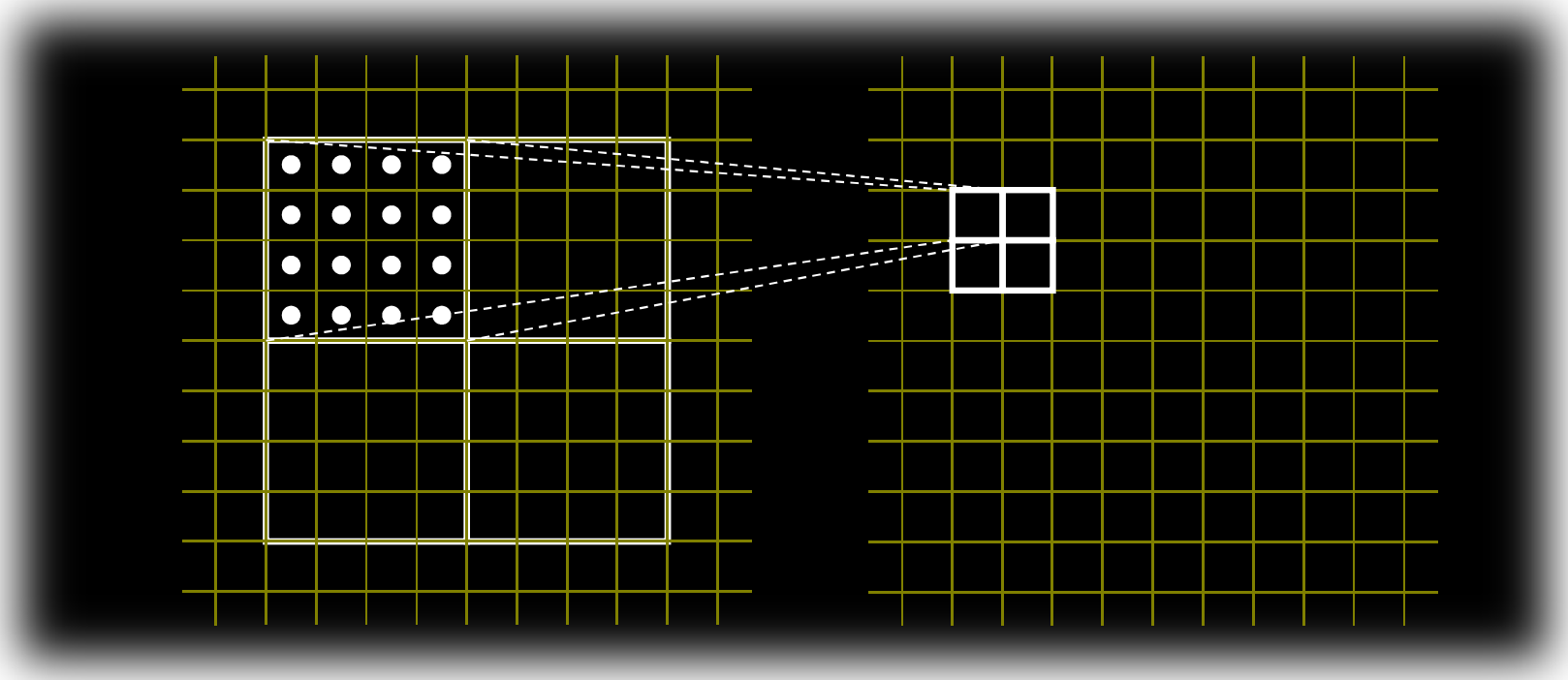
Super-Sampling

- **Ordered Grid Super-Sampling**
  - **Sub-sample grid is parallel and aligned to the horizontal and vertical axis**



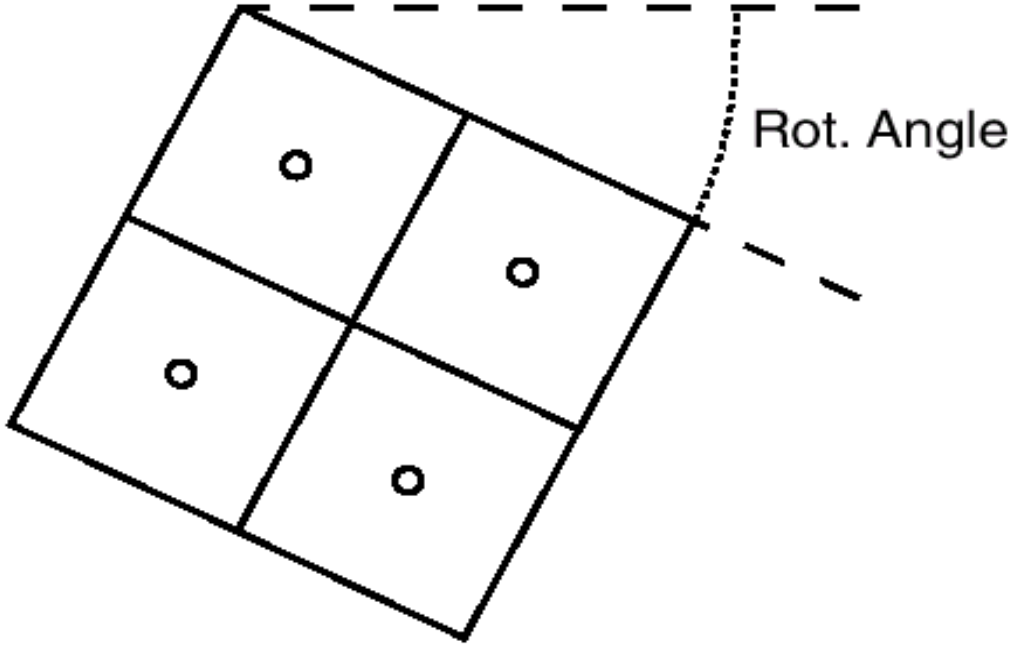
Super-Sampling

- Ordered Grid Super Sampling



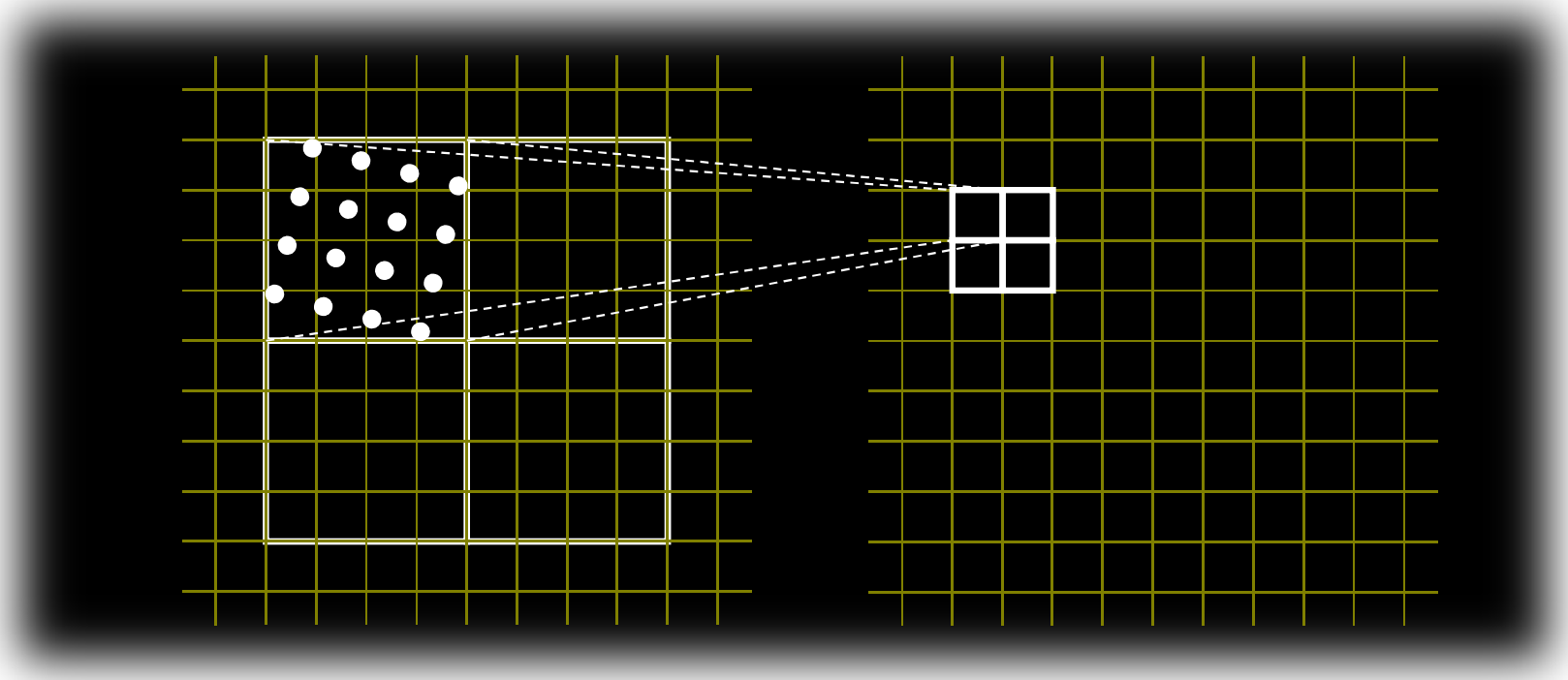
Super-Sampling

- **Rotated Grid Super-Sampling**
  - **The sub-sample grid is shifted off of the axis**



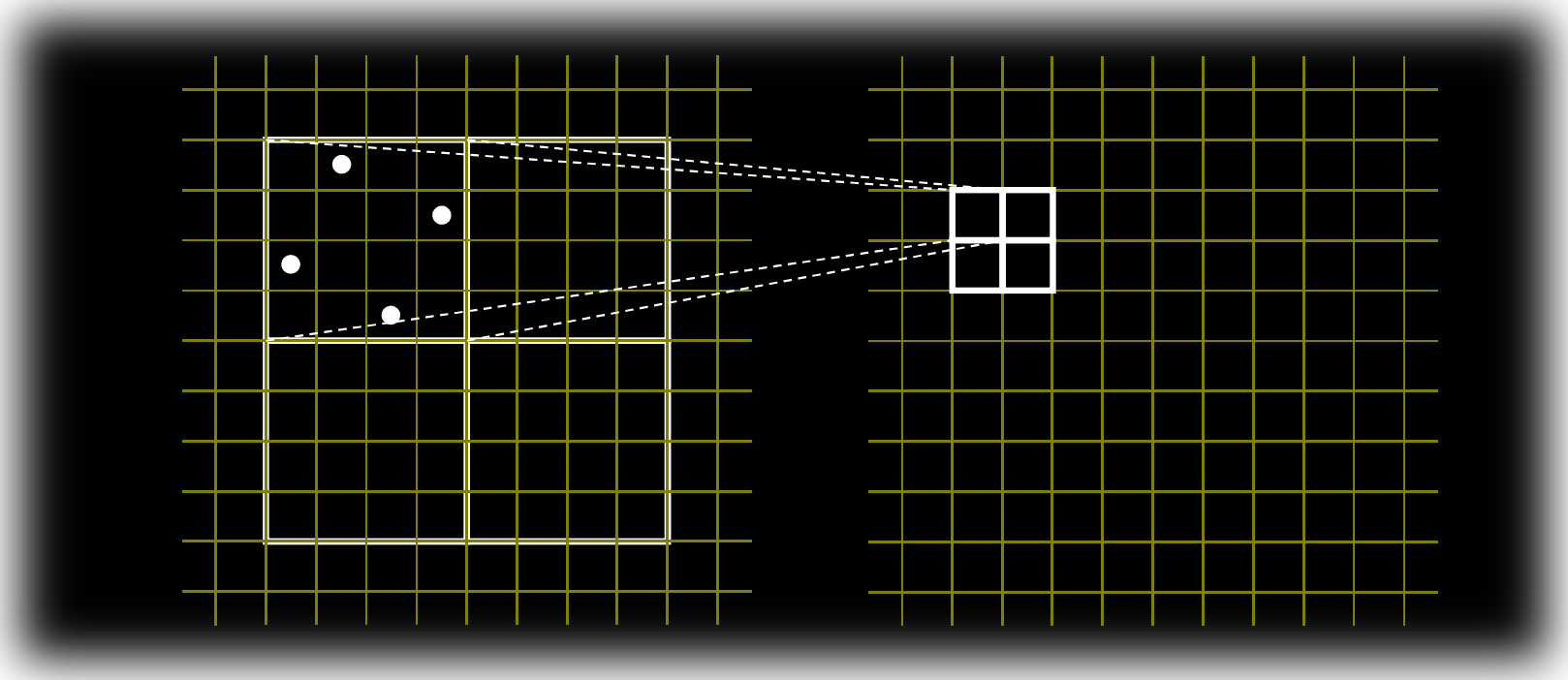
Super-Sampling

- Rotated Grid Super Sampling



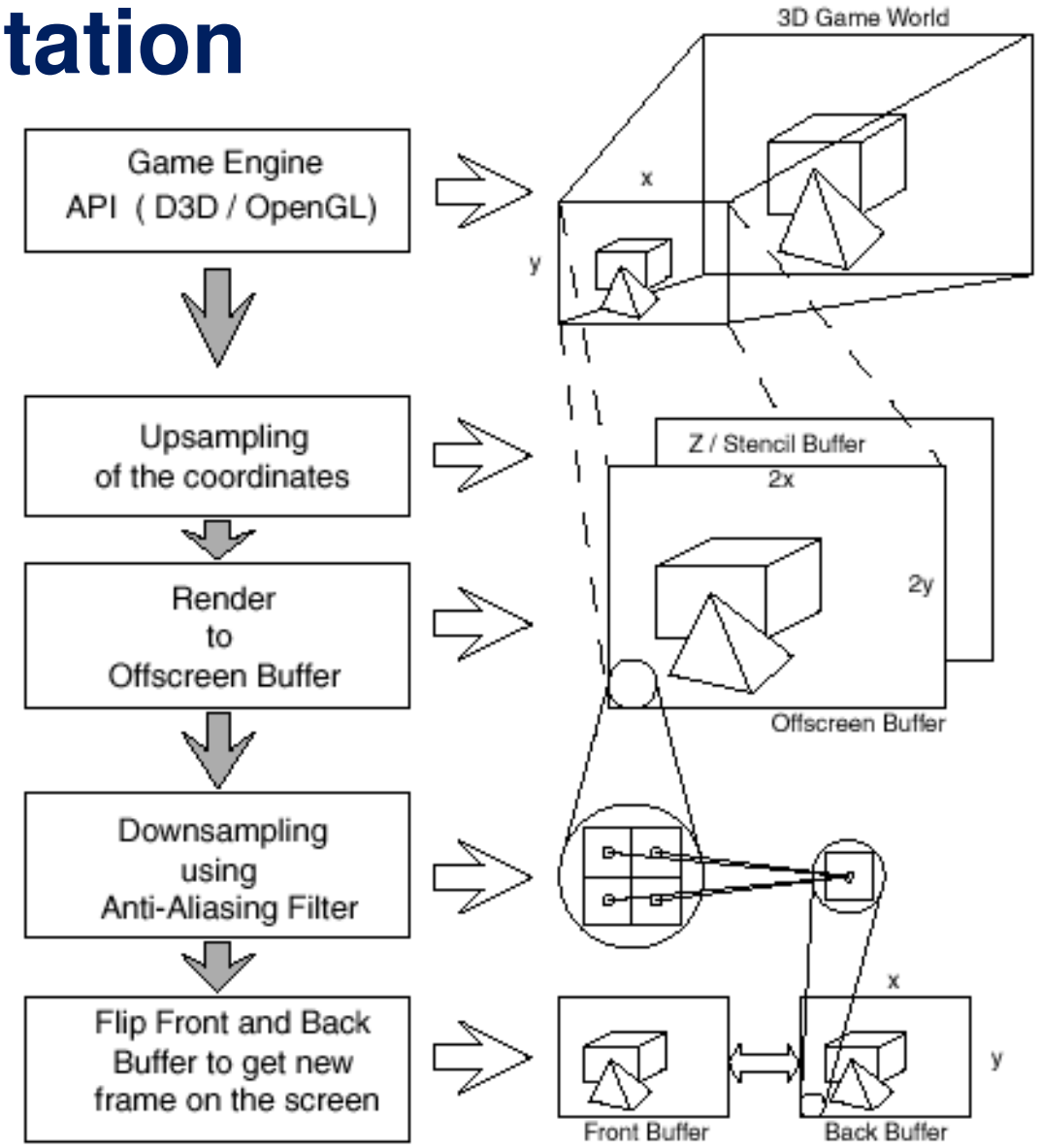
Super-Sampling

- Reduce the number of samples



Ordered Grid Super Sampling

- **An Implementation**



Rotated Grid Super Sampling

- An Implementation

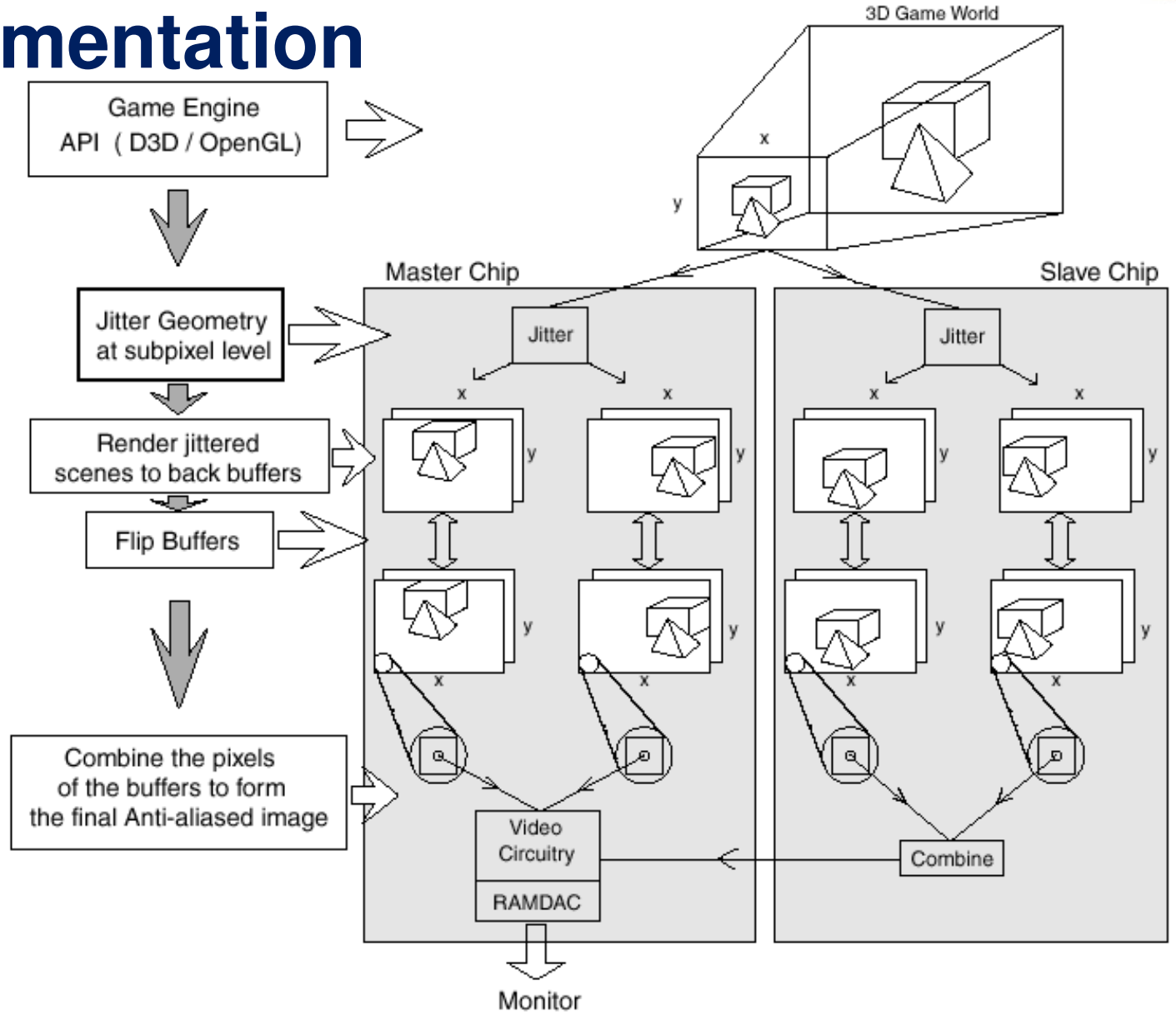


Image Quality (Near Horizontal)

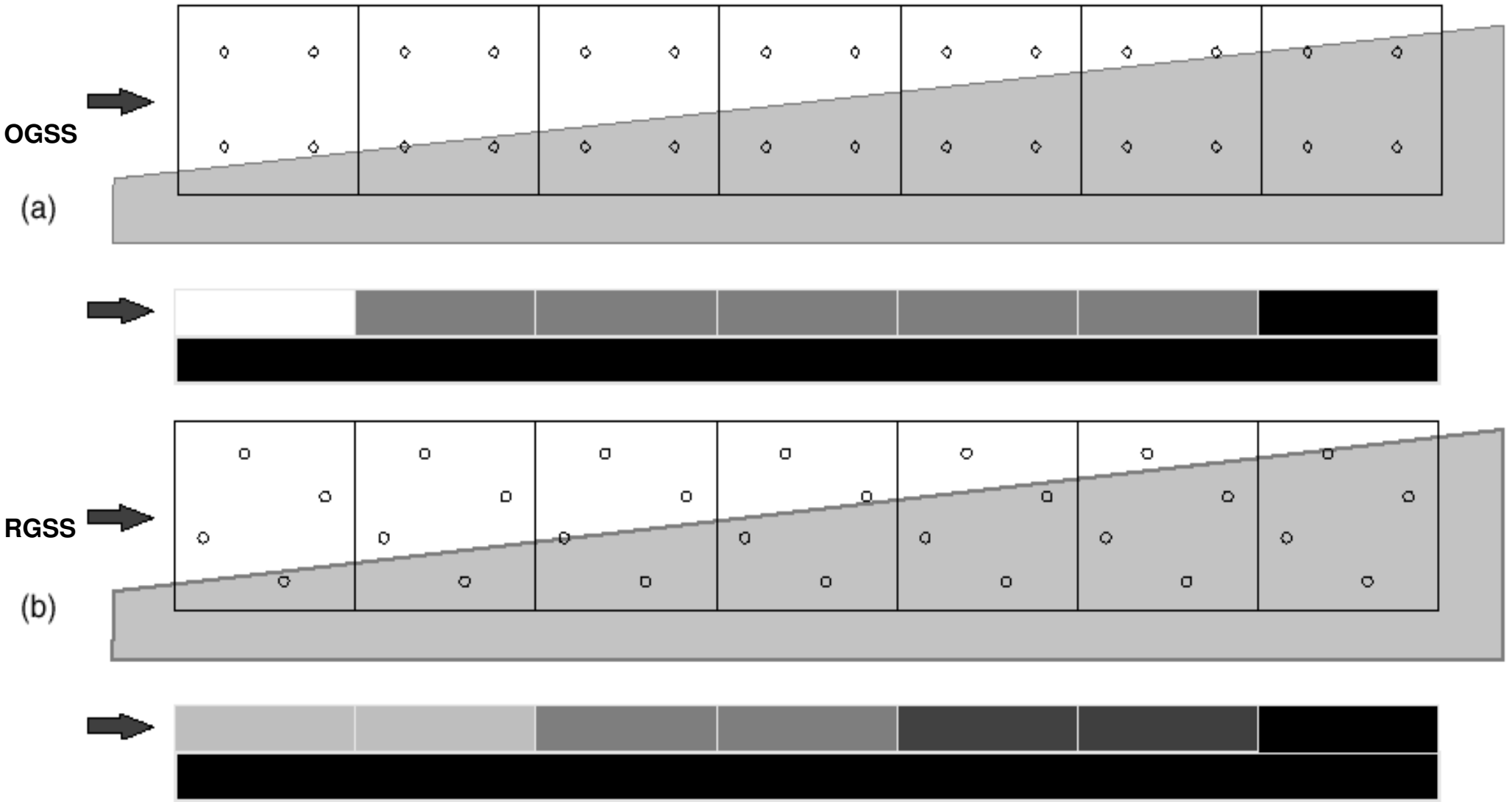
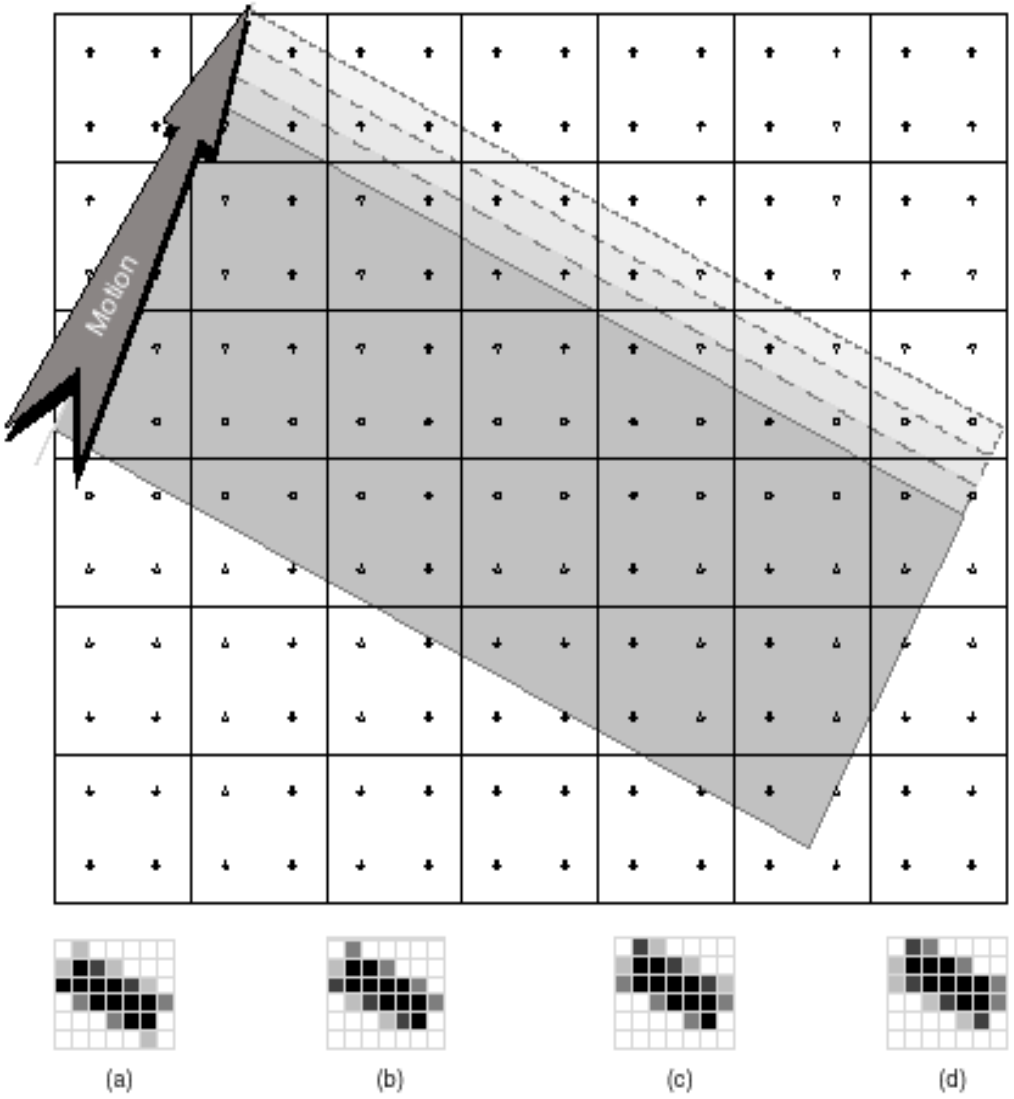


Image Quality



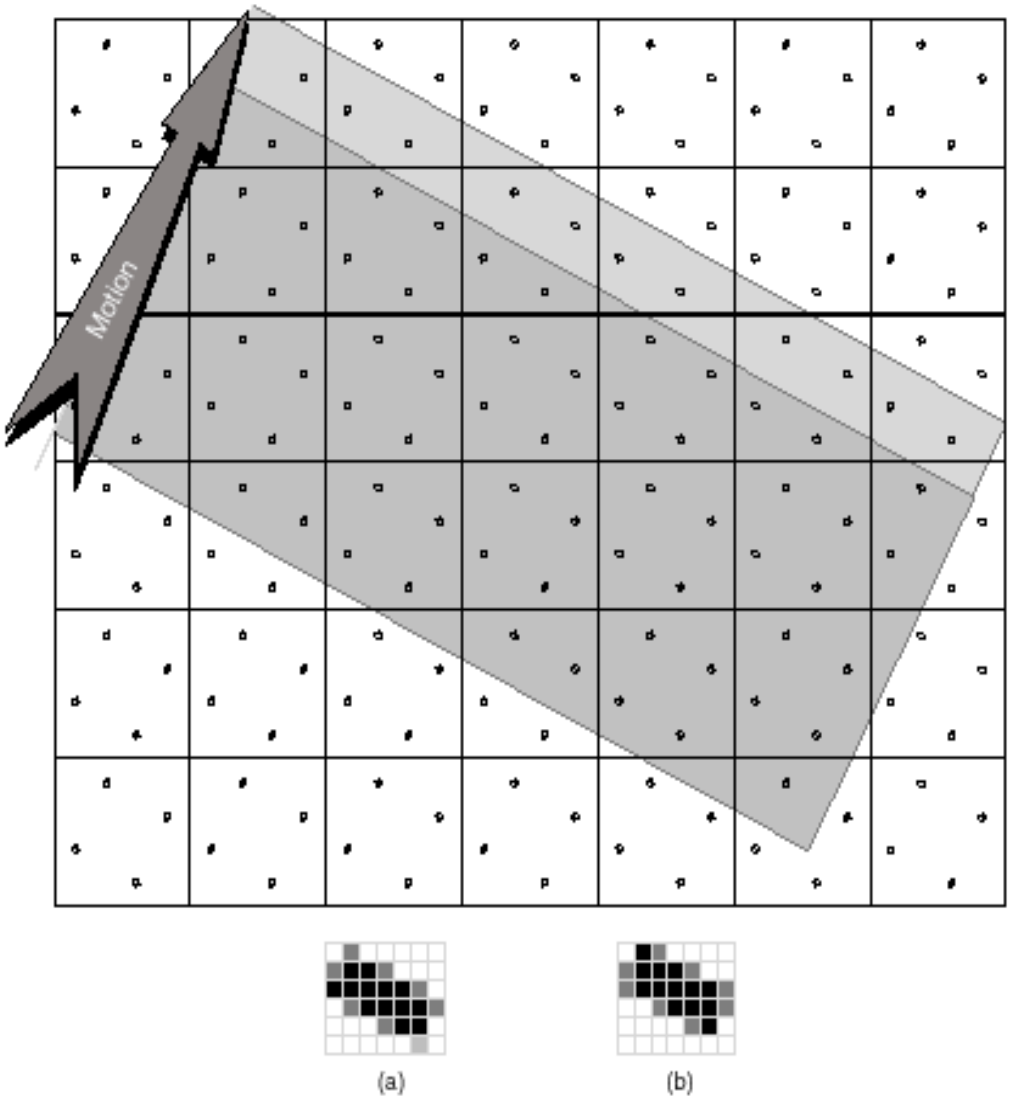
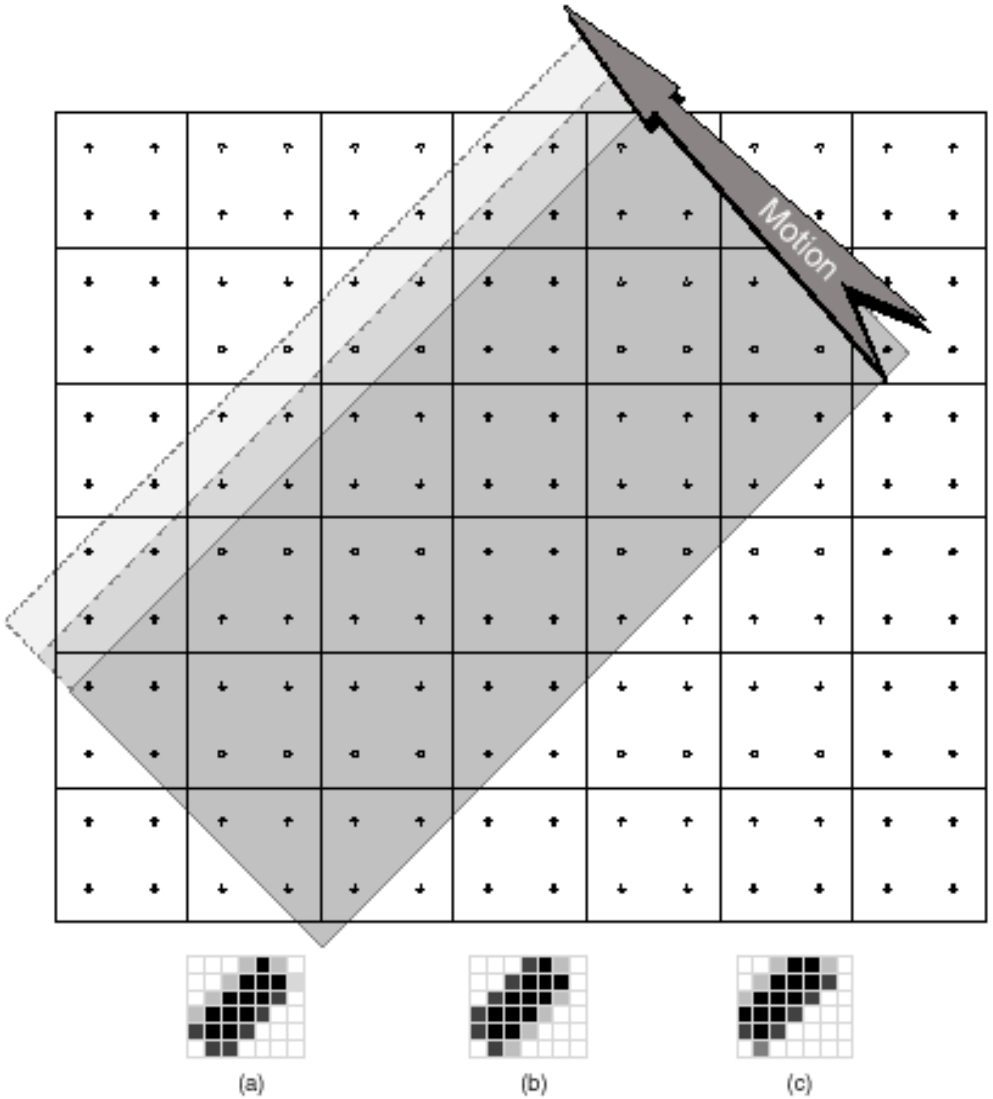


Image Quality (45 degree)



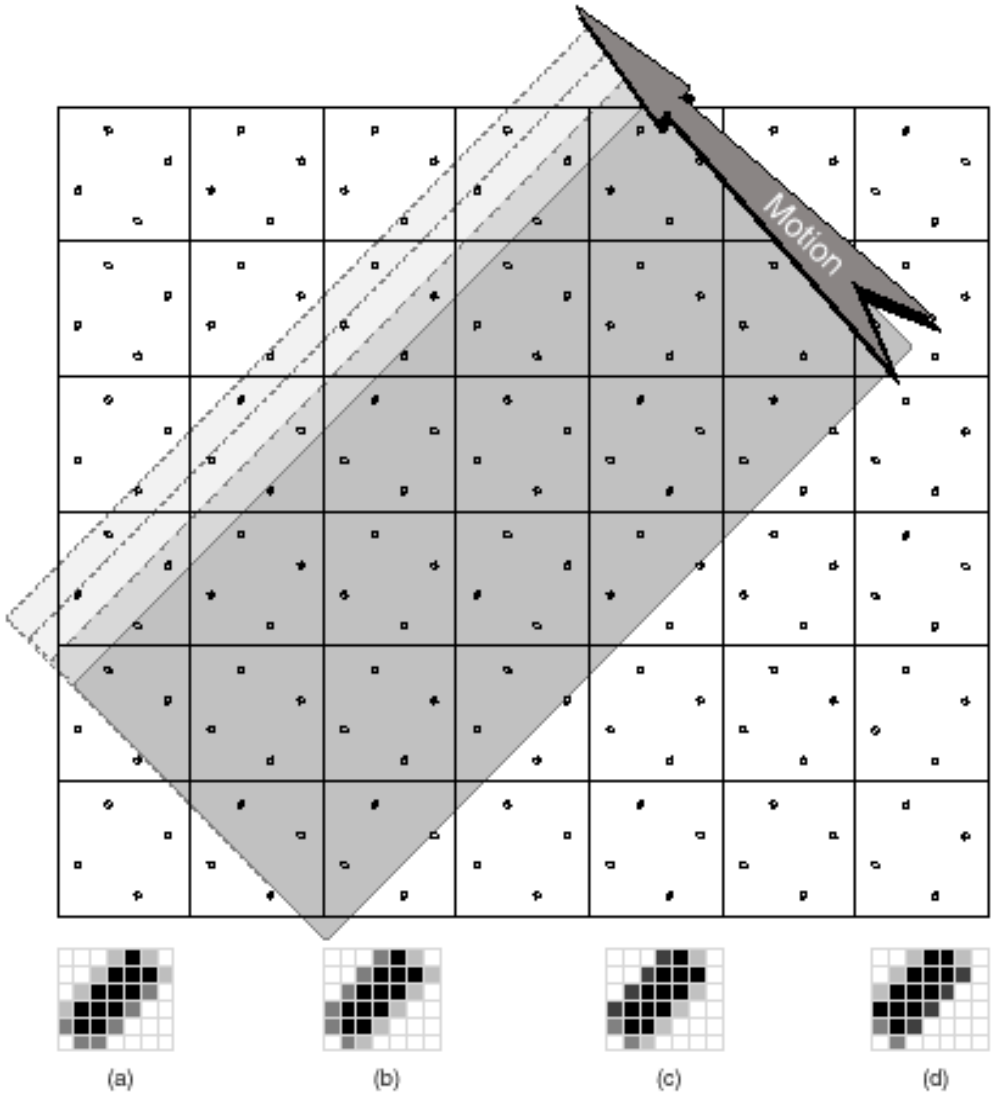
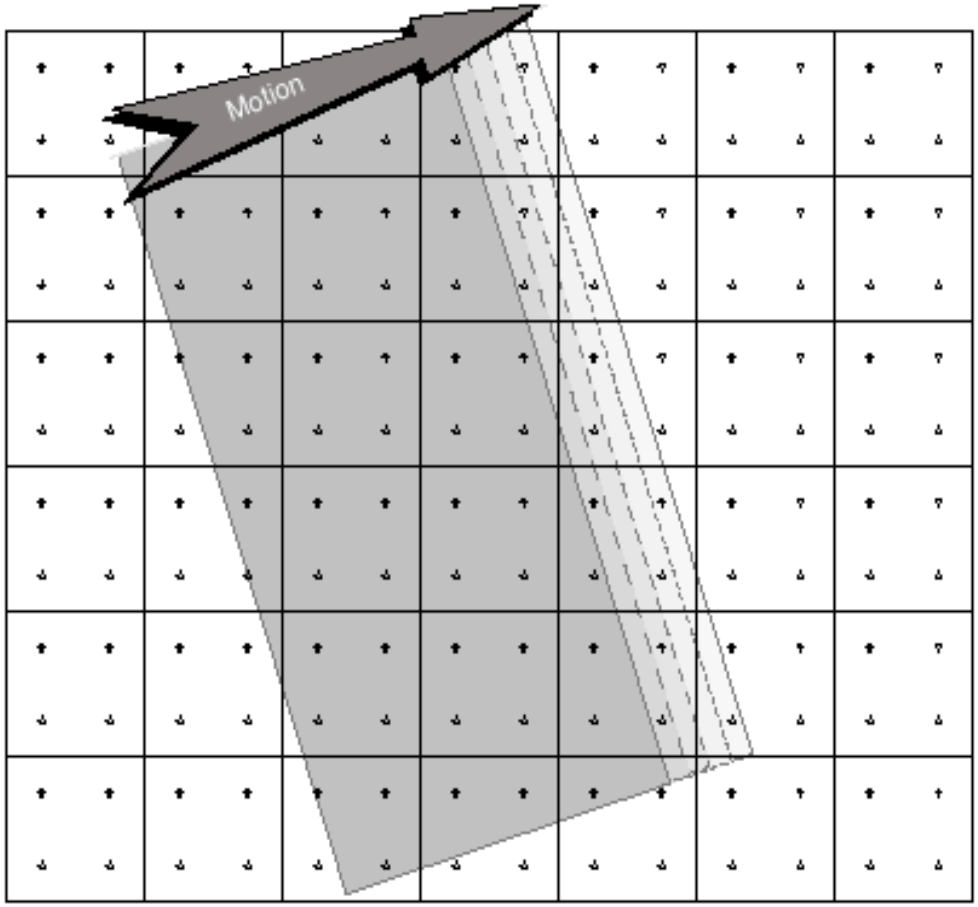
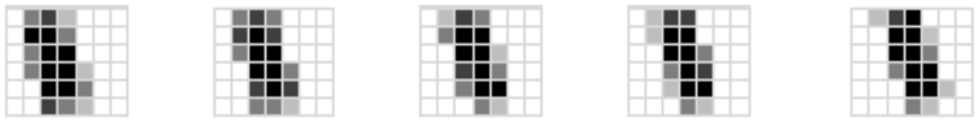
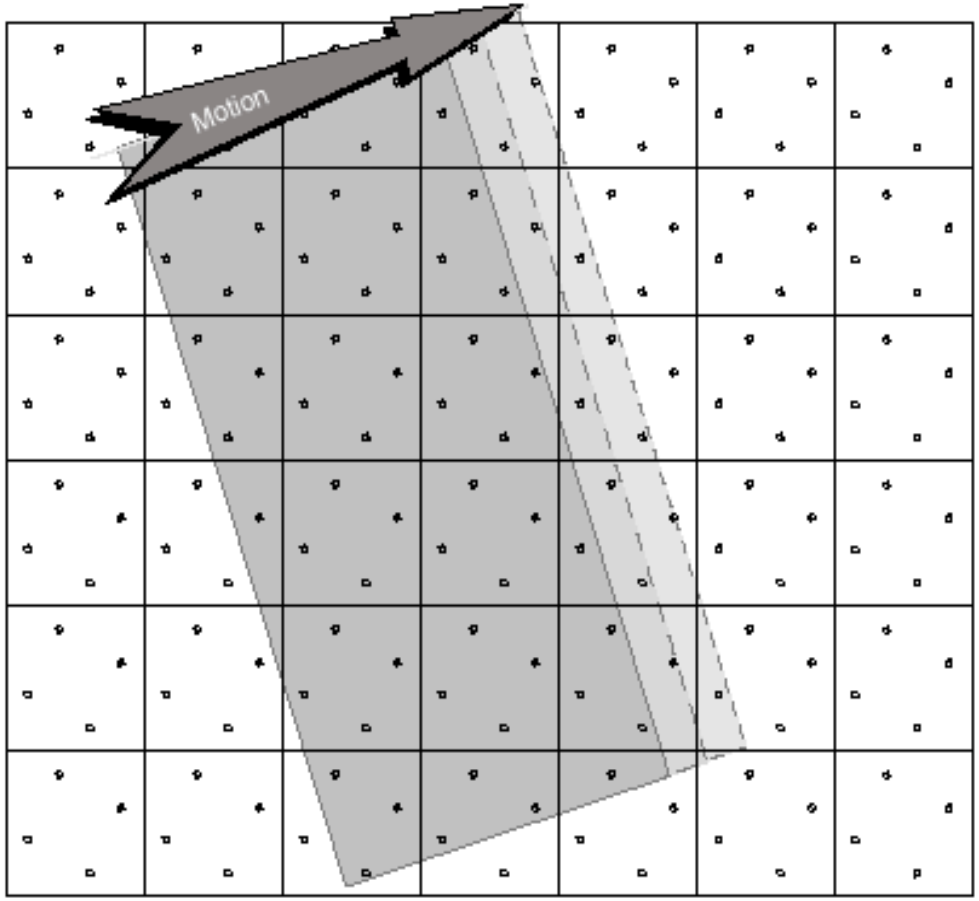
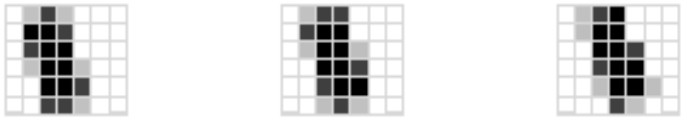


Image Quality (45+ degree)



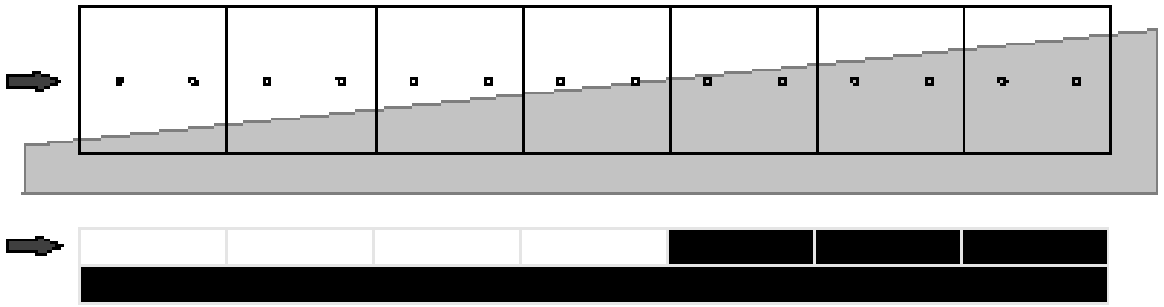




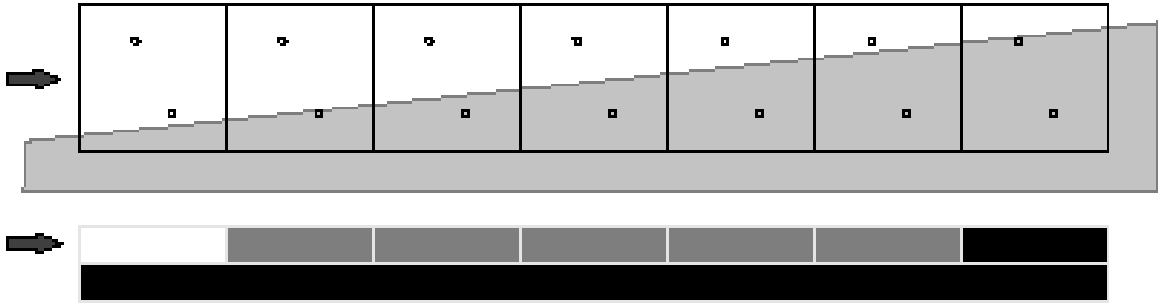


Comparison

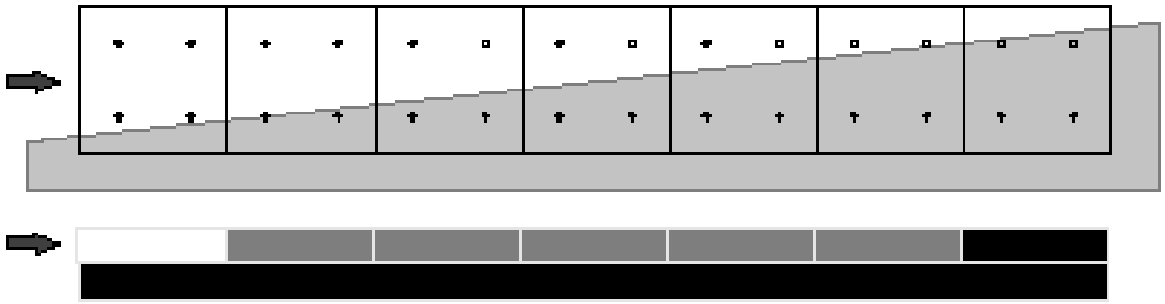
2 sampled OGSS



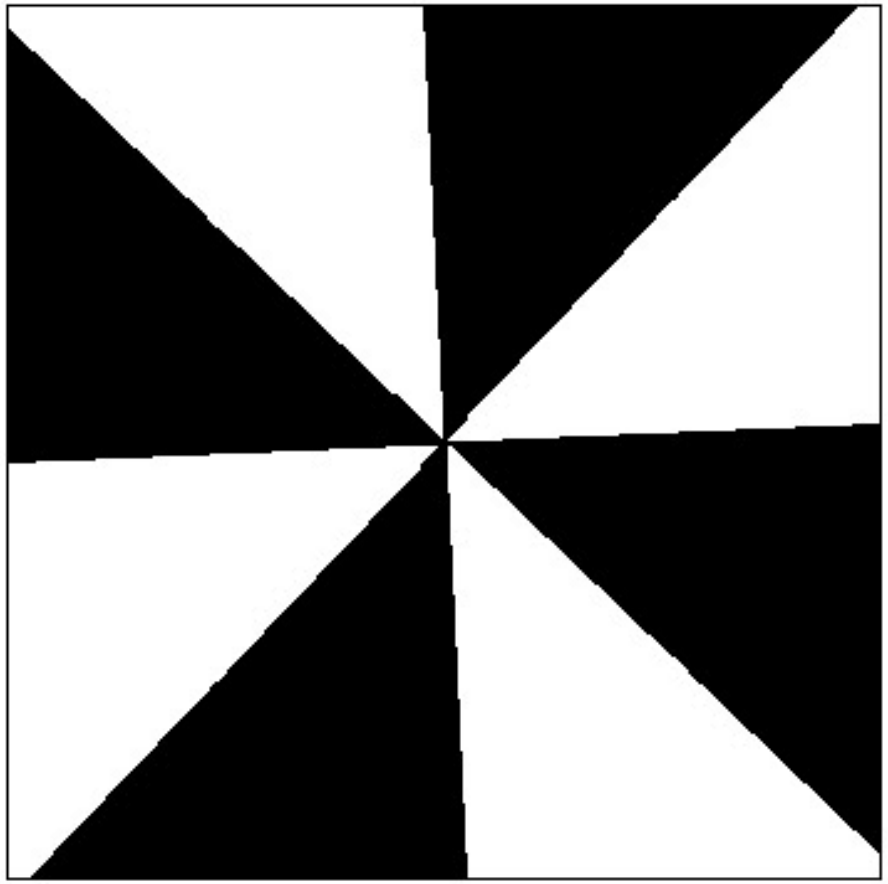
2 sampled RGSS

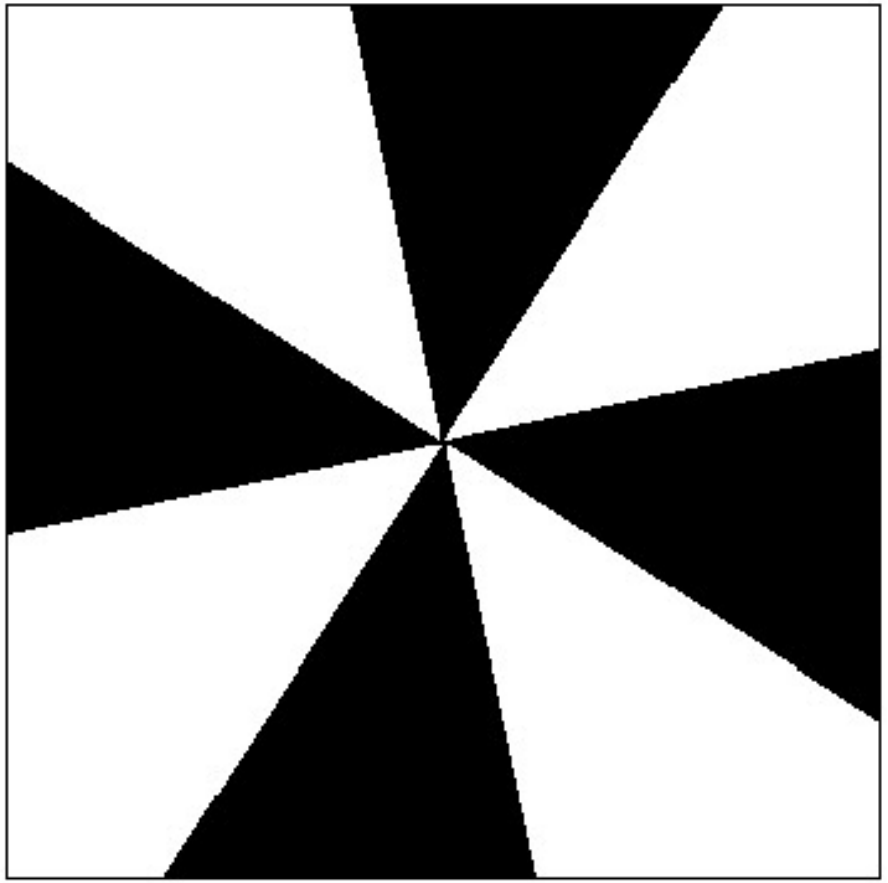


4 sampled OGSS



Eye Sensitivity to Different Angles



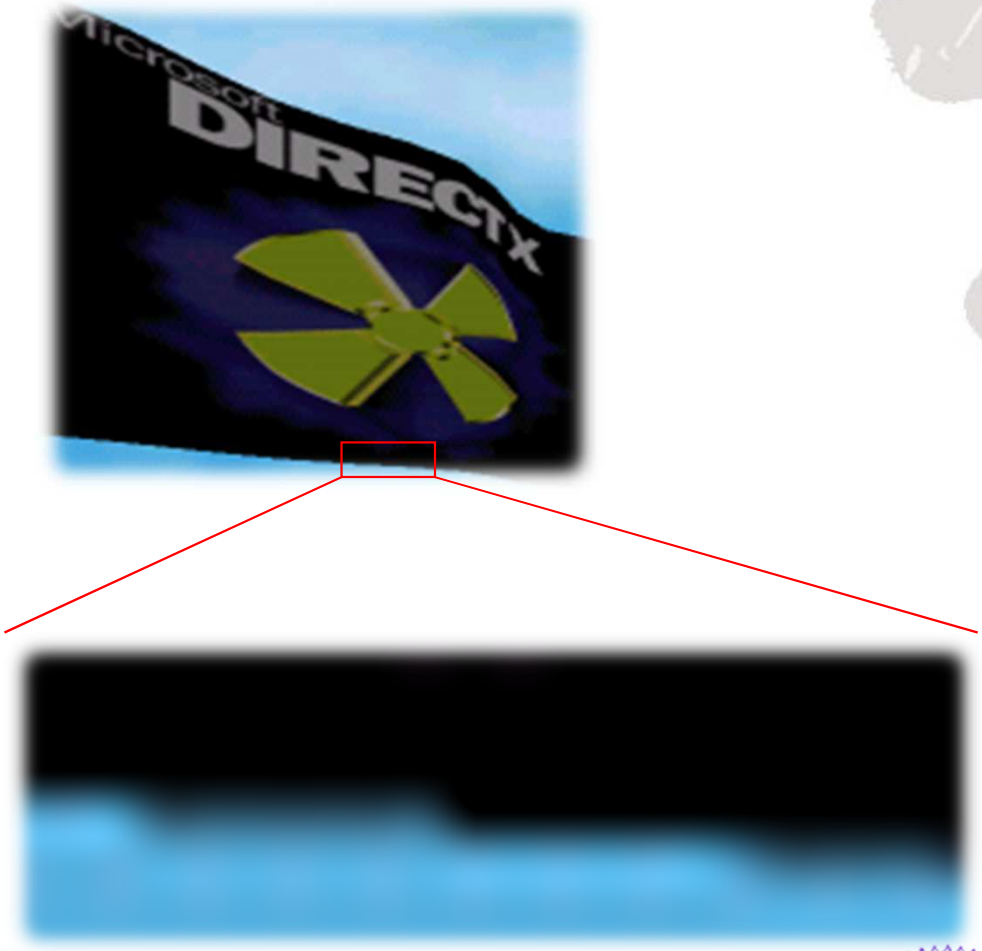


Some Findings

- Anti-aliasing improve the image quality, but always comes with performance cost.
- Higher resolution can only reduce the aliasing effect but not eliminate
- Typical rotating angle is about 20~30 degrees for RGSS
- RGSS is superior than OGSS
  - 2-sampled RGSS ≈ 4-sample OGSS

Anti-Aliasing Result

Without Anti-asliasing



With Anti-asliasing

Anti-Aliasing Result

Non anti-aliasing

OGSS

RGSS

Anti-Aliasing Result

Non anti-aliasing

OGSS

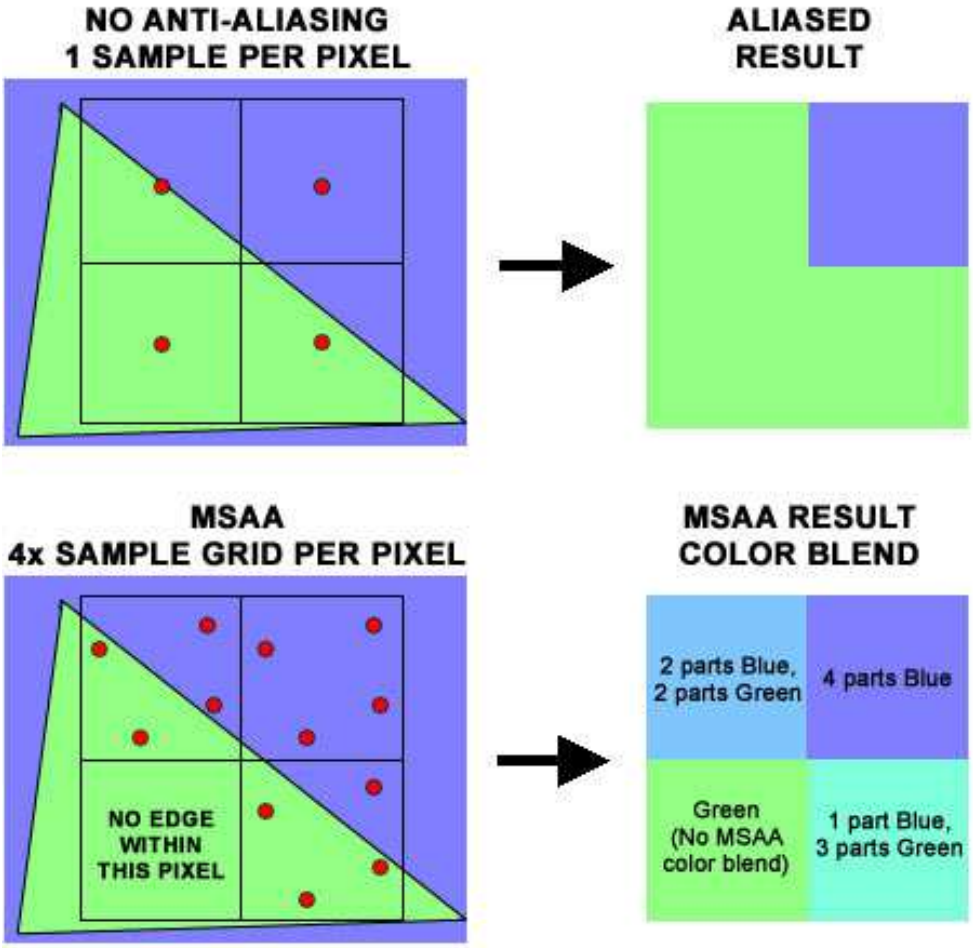
RGSS

Multi-Sample AA (MSAA)

- Similar to super-sampling
- Sample texture once for all sub-samples in a pixel

MSAA

- Sample texture once for all sub-samples in a pixel

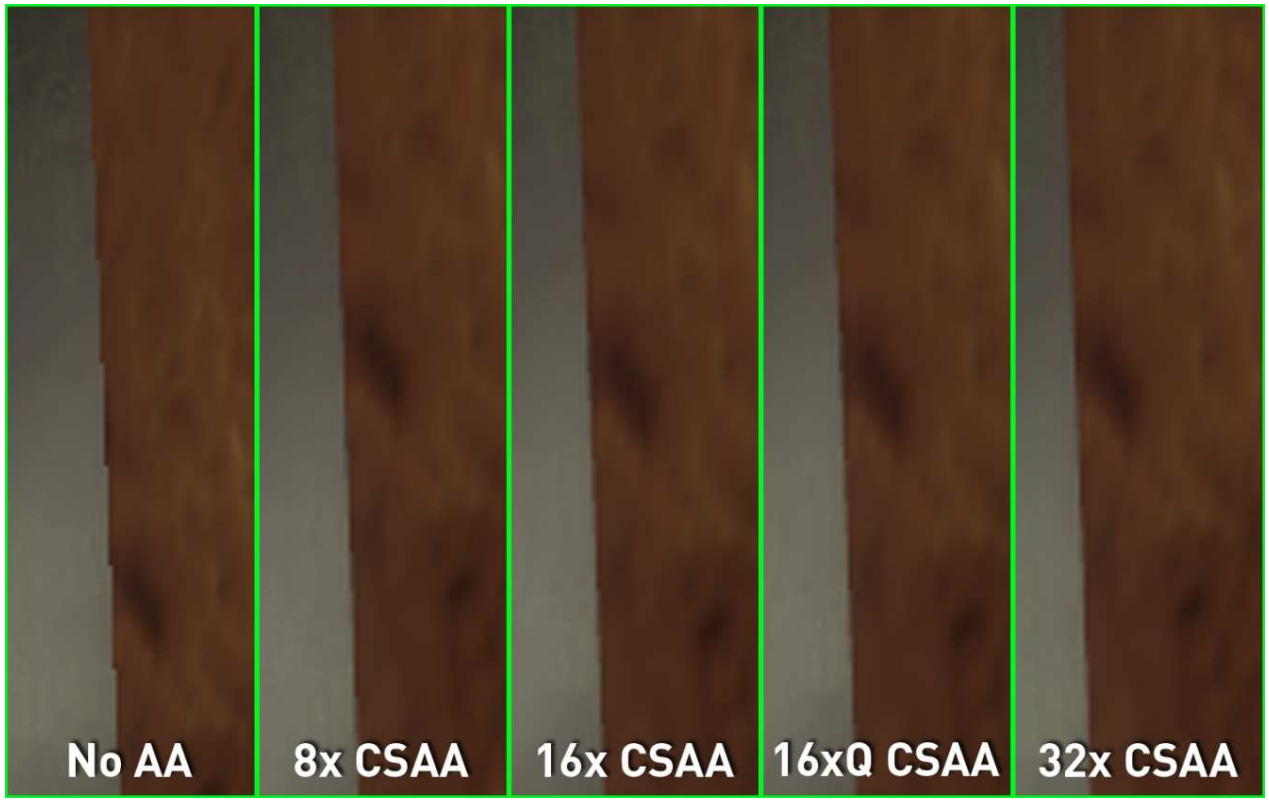


More than just SSAA and MSAA

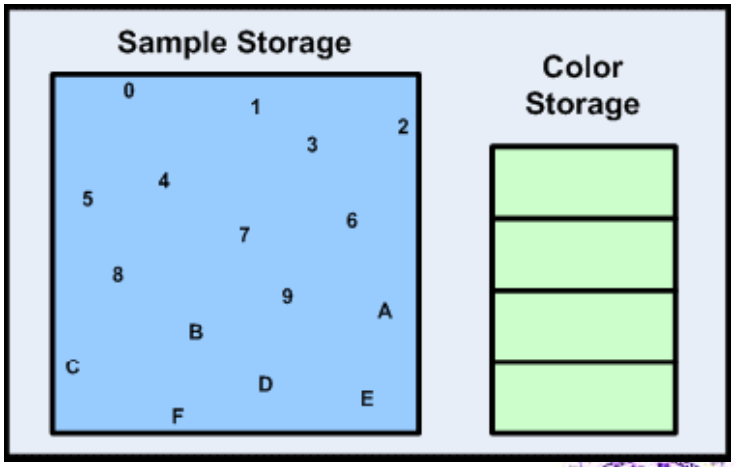
- CSAA (Coverage Sampling AA)
- AMSAA (Adaptive MSAA)
- Transparency AA
- CFAA (Custom Filter AA)
- SMAA (Subpixel Morphological AA)
- FXAA (Fast Approximate AA)
- SRAA (Subpixel Reconstruction AA)
- MLAA (Morphological AA)
- TXAA (Temporal AA)
- …

Coverage Sampling AA (CSAA)

- Decouple coverage samples from ordinary color samples

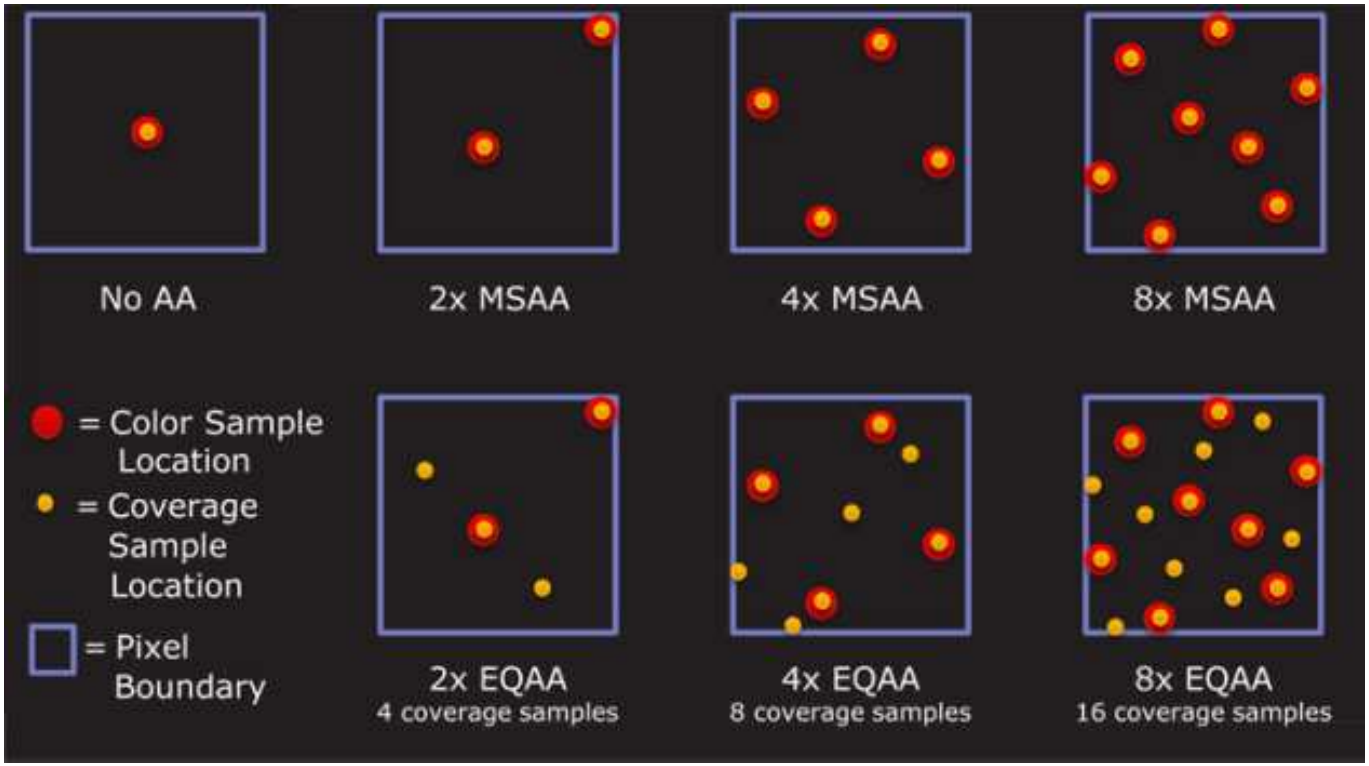


CSAA Mode	colorSamples value	coverageSamples value
8x	4	8
8xQ (Quality)	8	8
16x	4	16
16xQ (Quality)	8	16



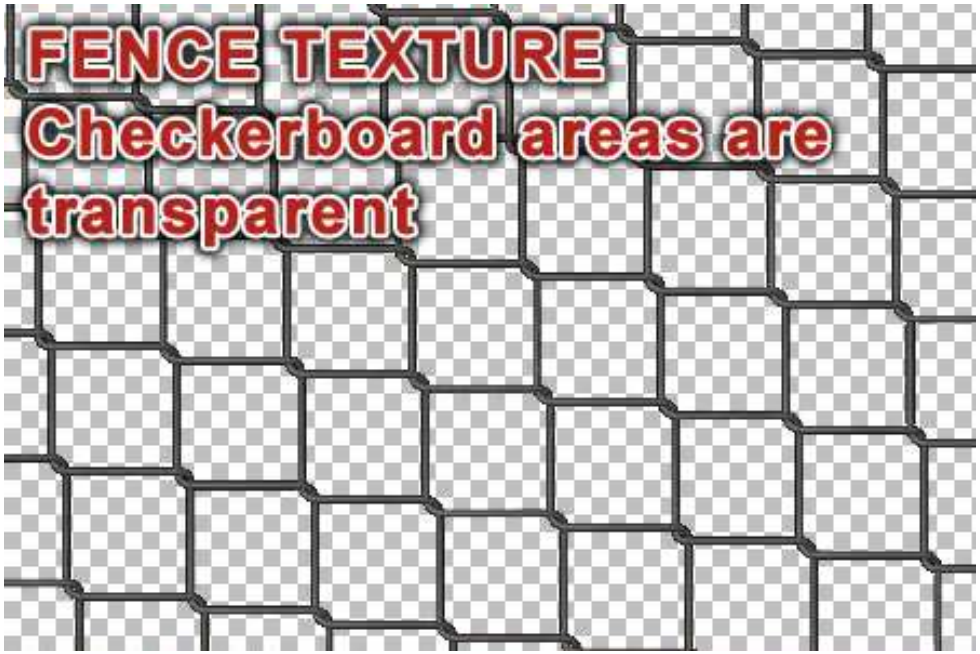
Coverage Sampling AA (CSAA)

- Similar to Enhanced Quality AA (EQAA)



Adaptive AA and Transparency AA

- Solving texture aliasing with alpha transparency in texels



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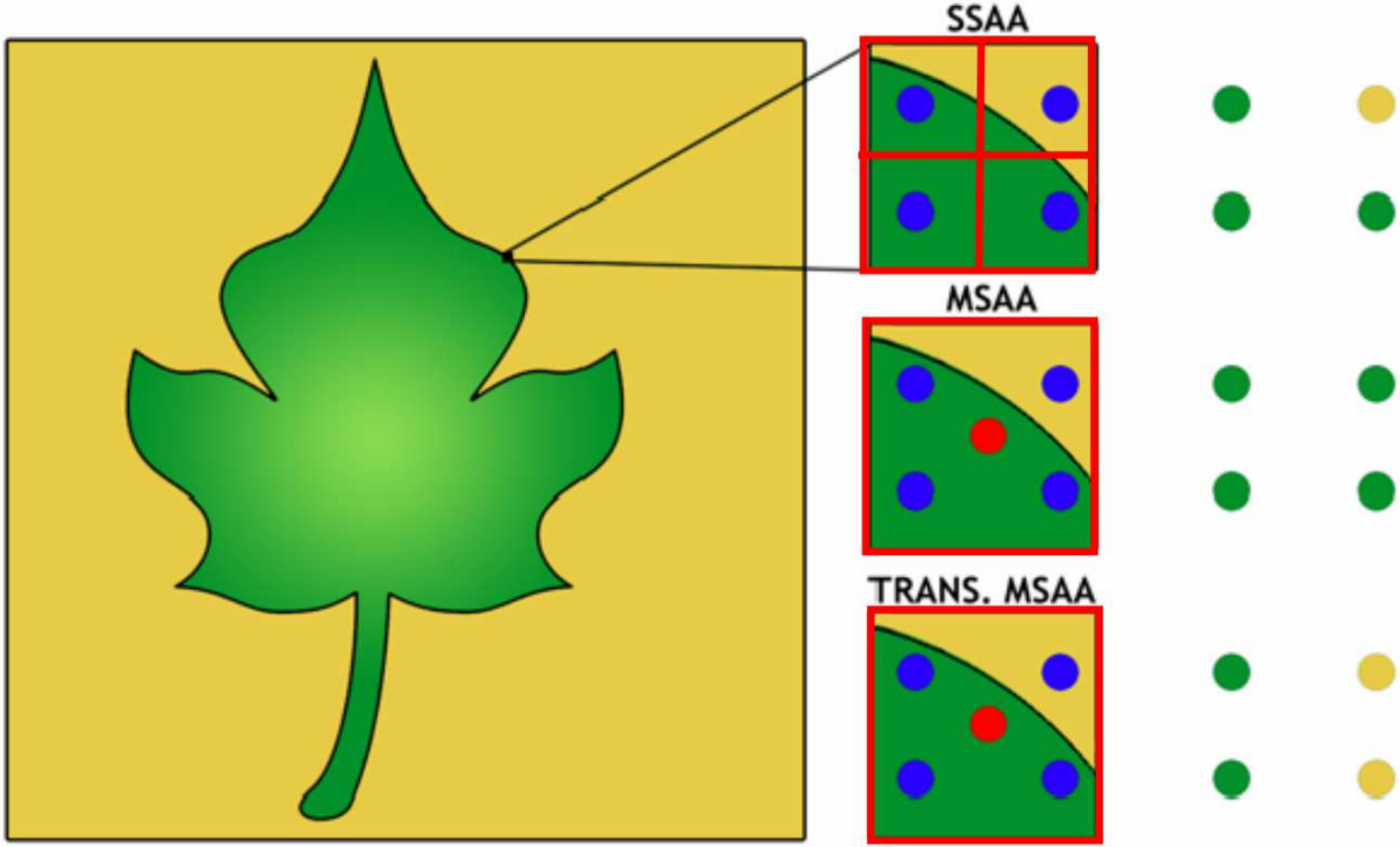
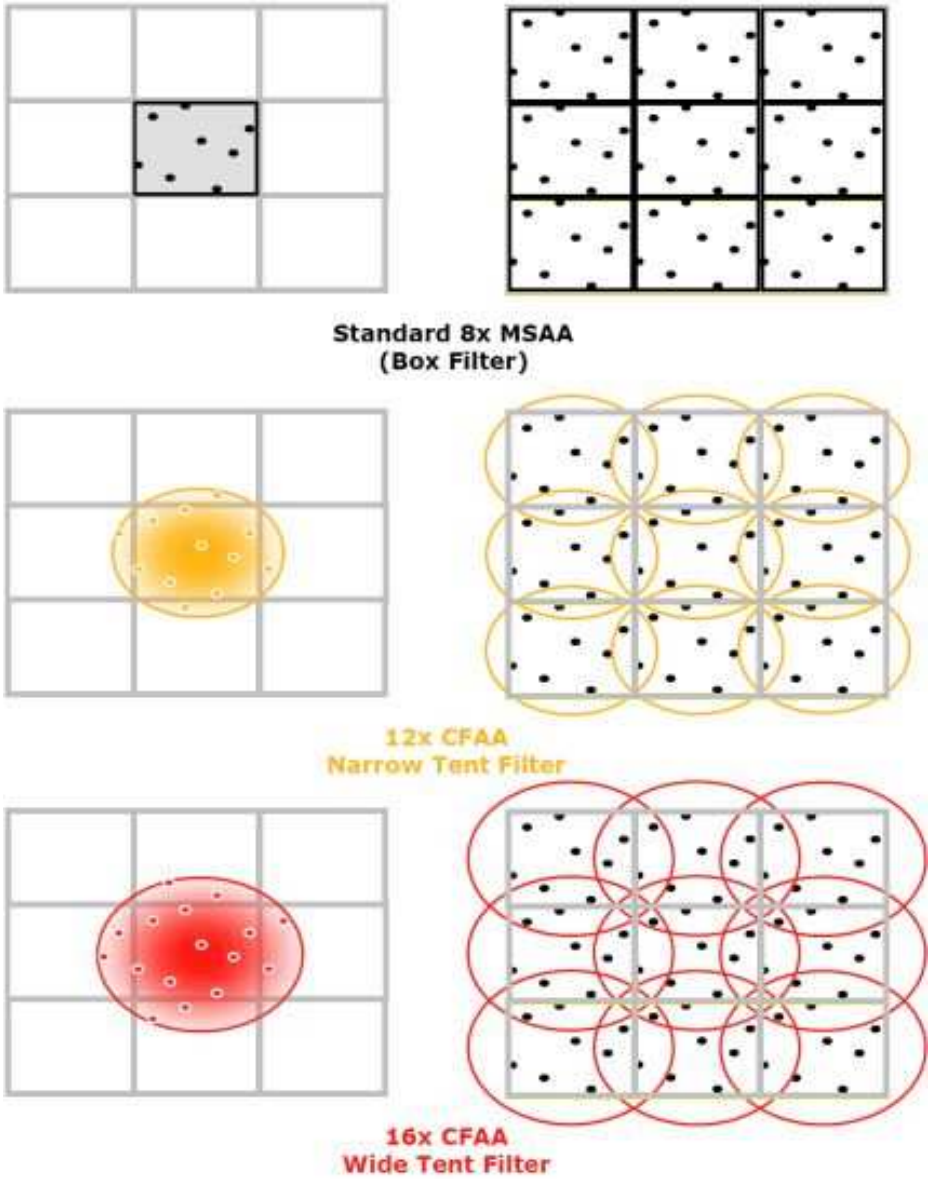


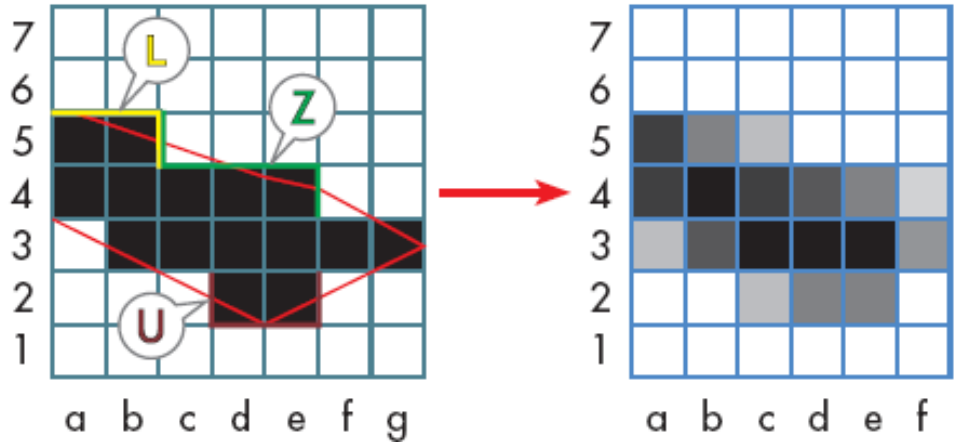
Custom Filter AA (CFAA)

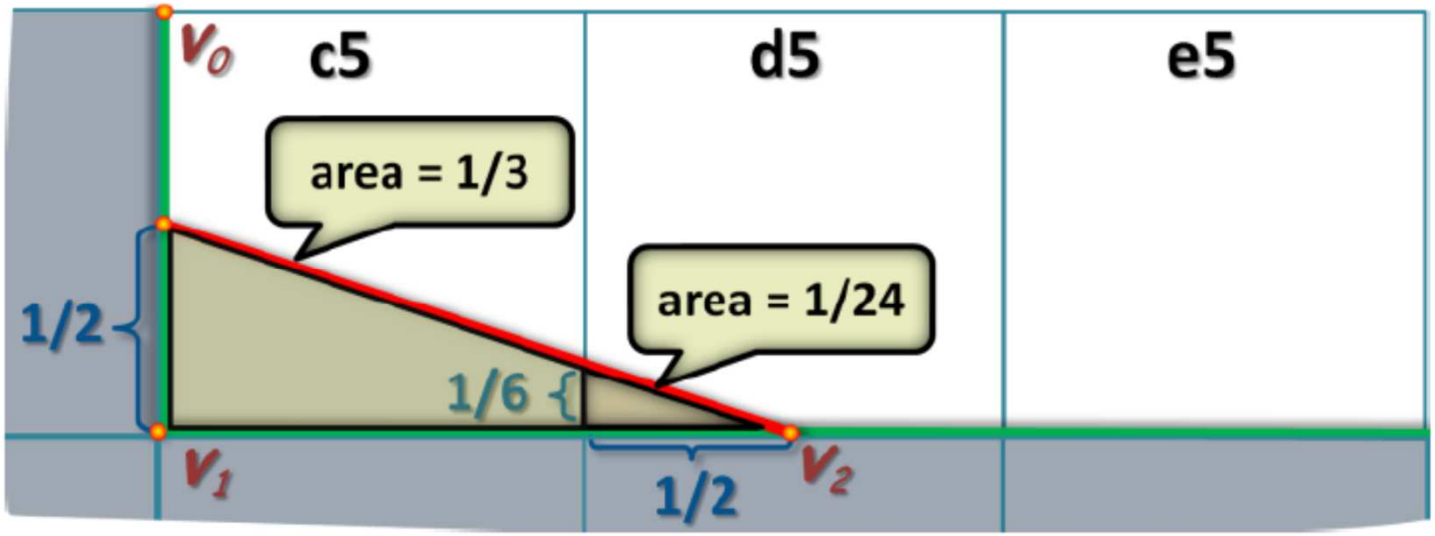
Custom Filter AA (CFAA)



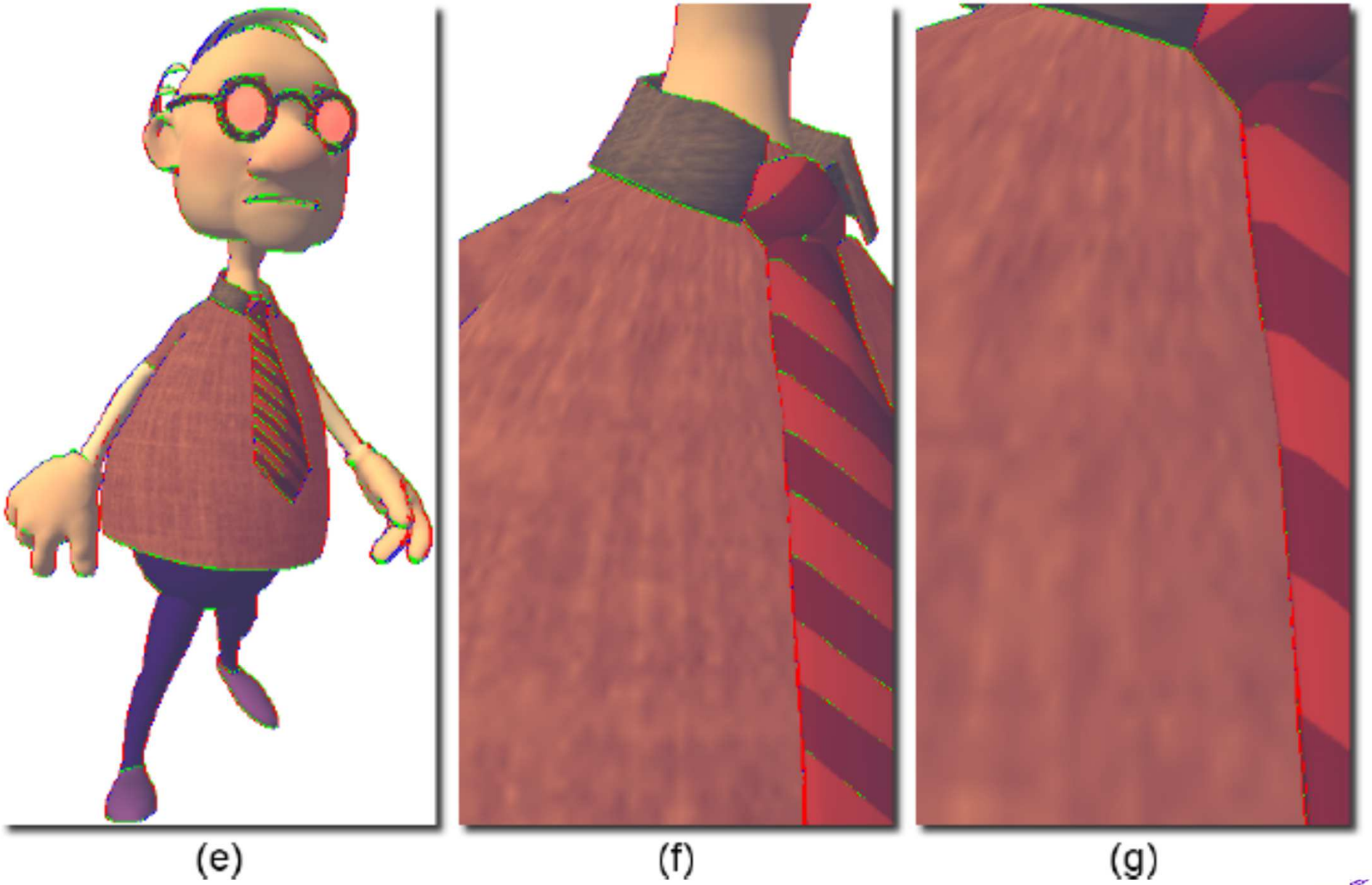
Morphological AA (MLAA)

- Smooth out jaggies using post processing





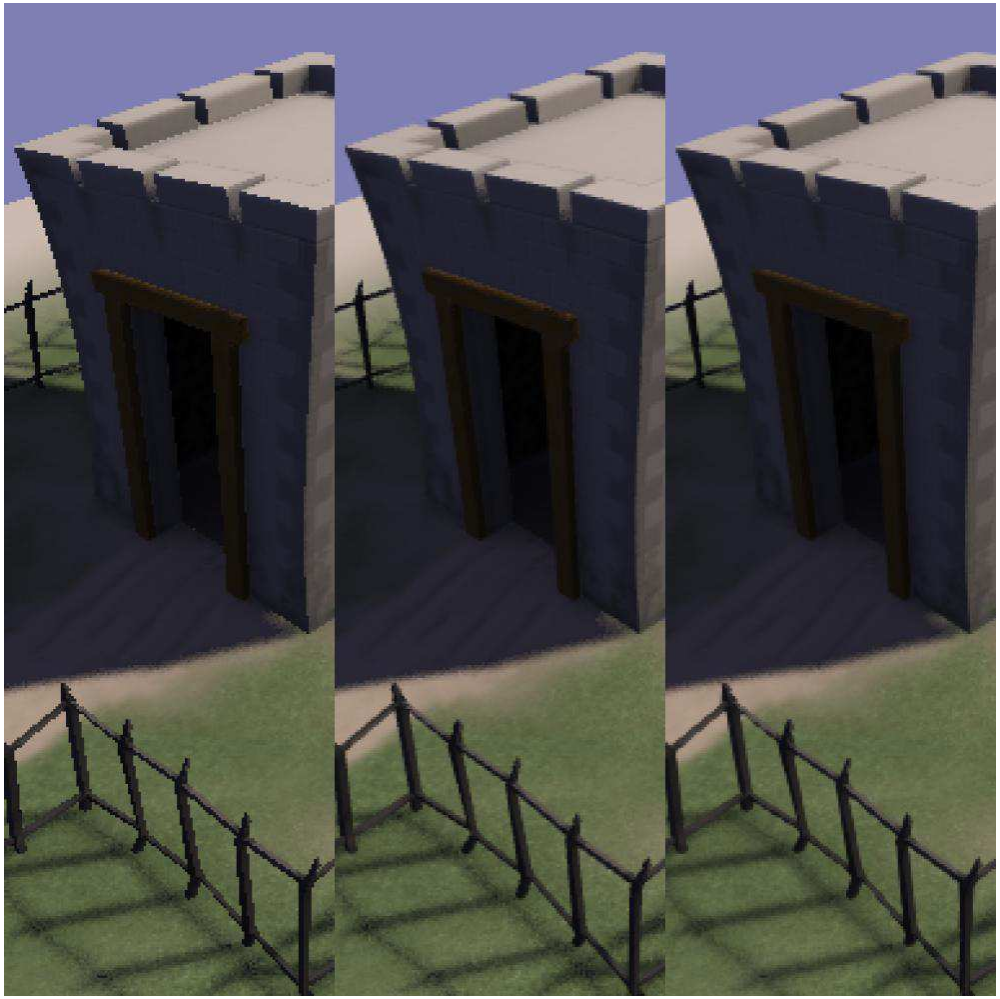
Morphological AA (MLAA)



(e) (f) (g)

FXAA

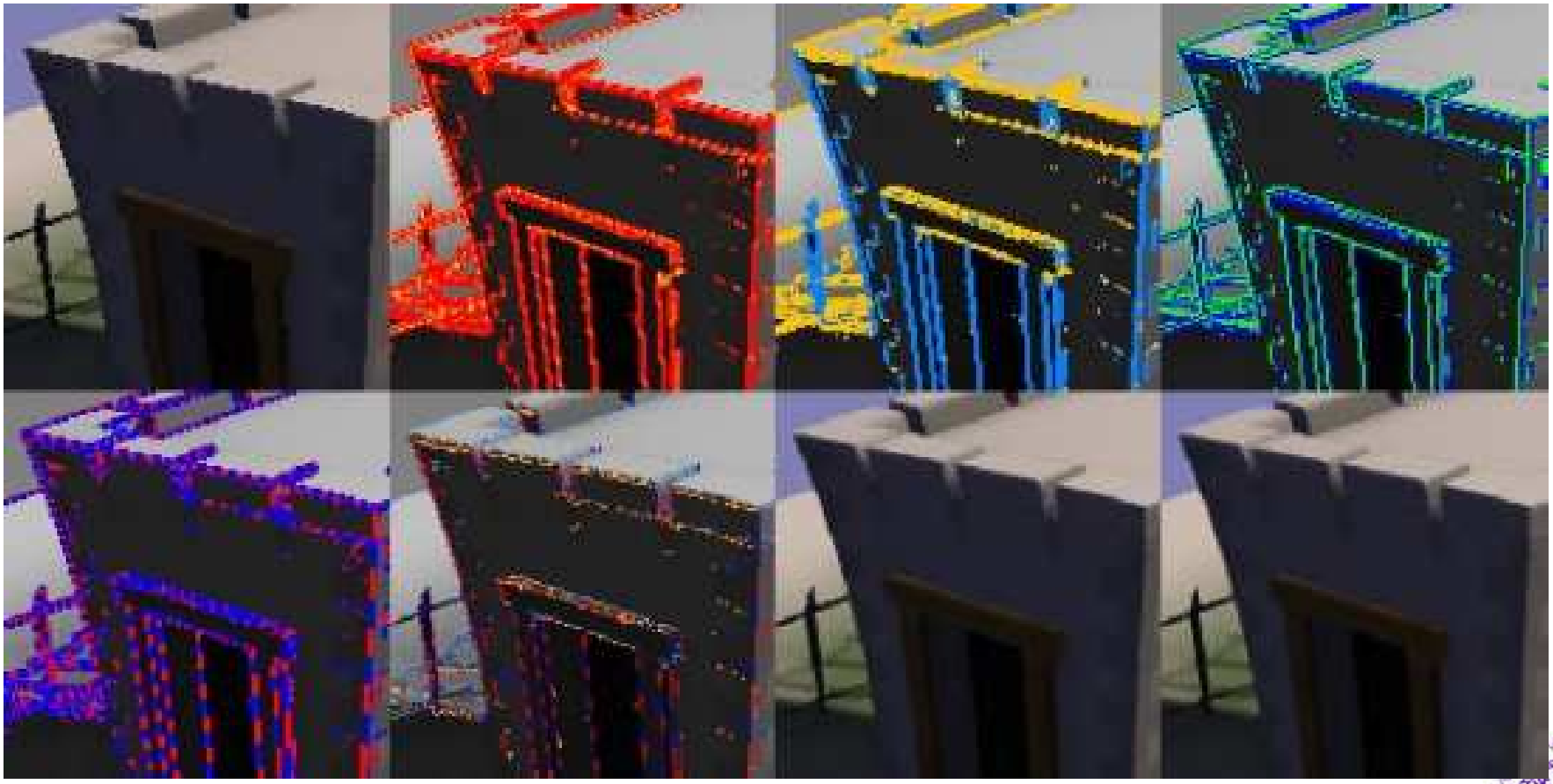
- Fast Approximate AA (post processing)



No AA 4xMSAA FXAA

FXAA

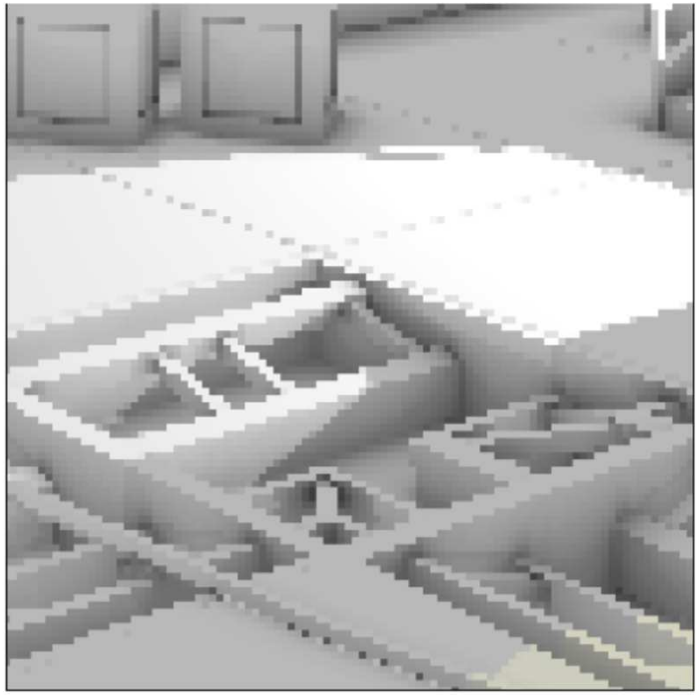
- Find all the edges and smooth the edges



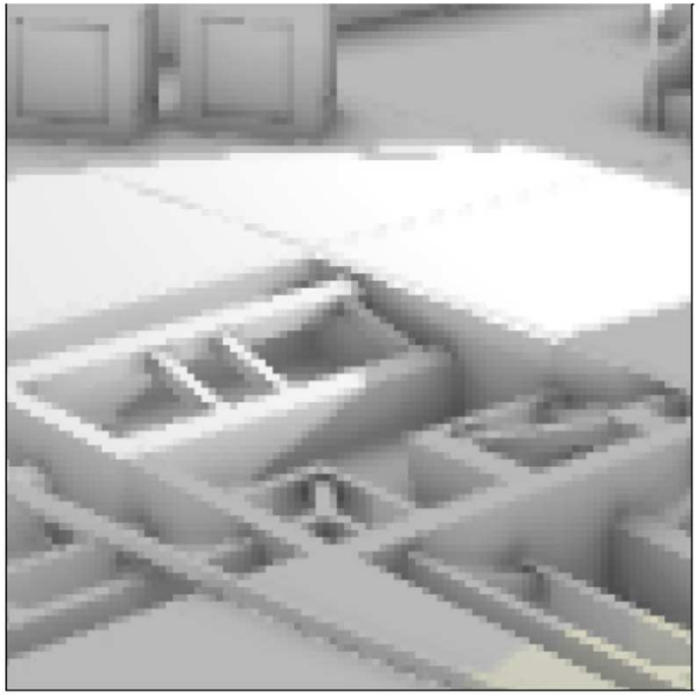
Subpixel Reconstruction AA

← *Similar Time* →

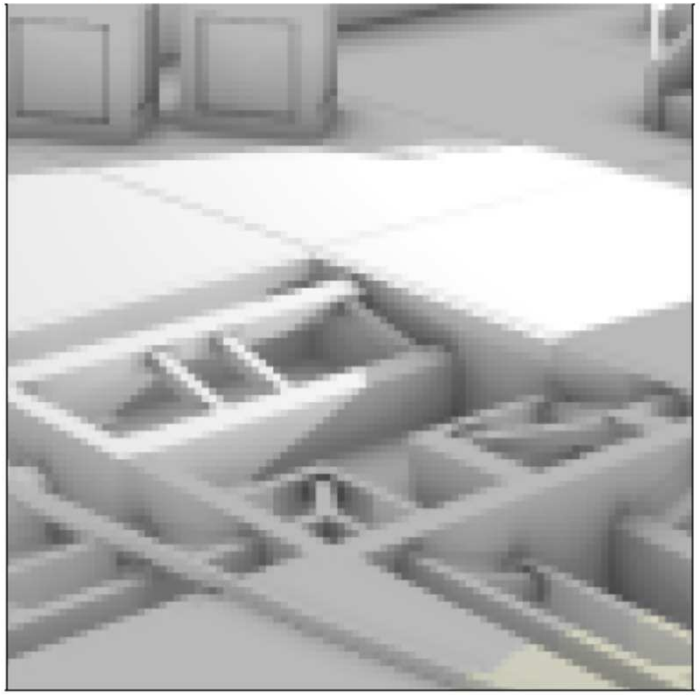
← *Similar Quality* →



(a) 1× Shading + Box (poor, fast)

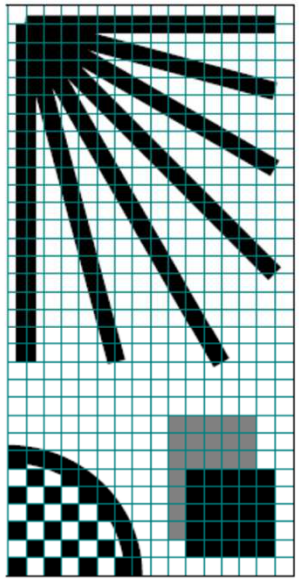


(b) **NEW: 1× Shading + SRAA (good, fast)**

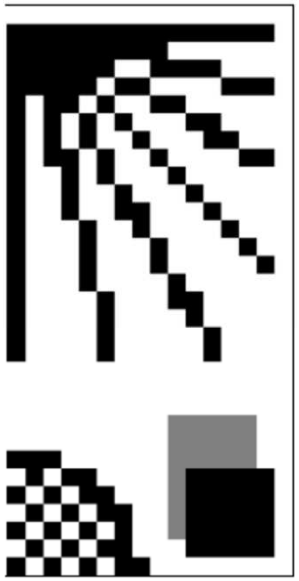


(c) 16× Shading + Box (good, slow)

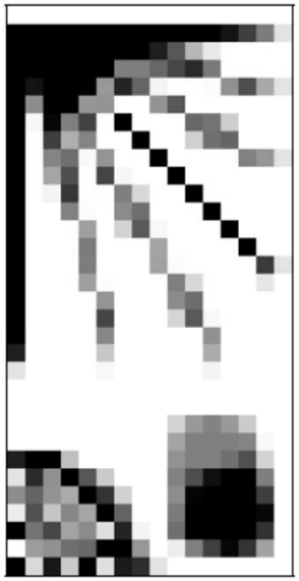
Subpixel Reconstruction AA



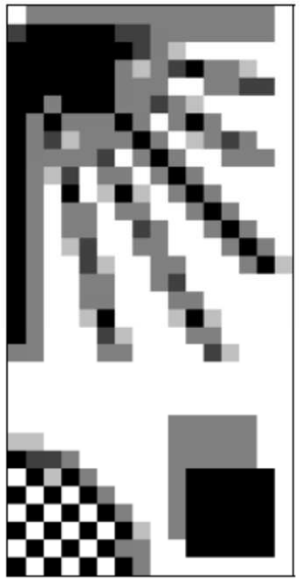
(a) Vector Input



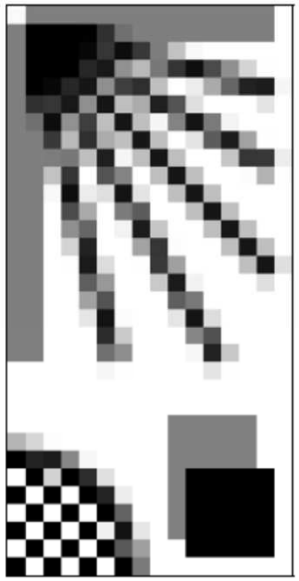
(b) 1× Shading



(c) 1× Shading + MLAA



(d) 1× Shading + New SRAA



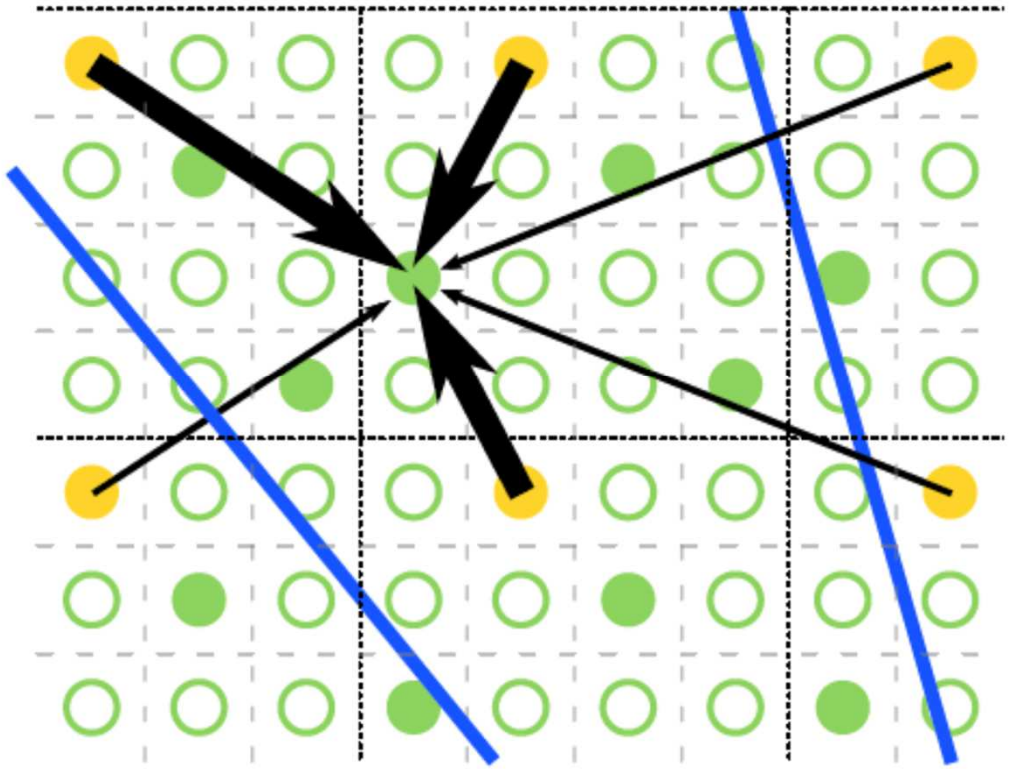
(e) 16384× Shading Reference

Subpixel Reconstruction AA

Shaded sample

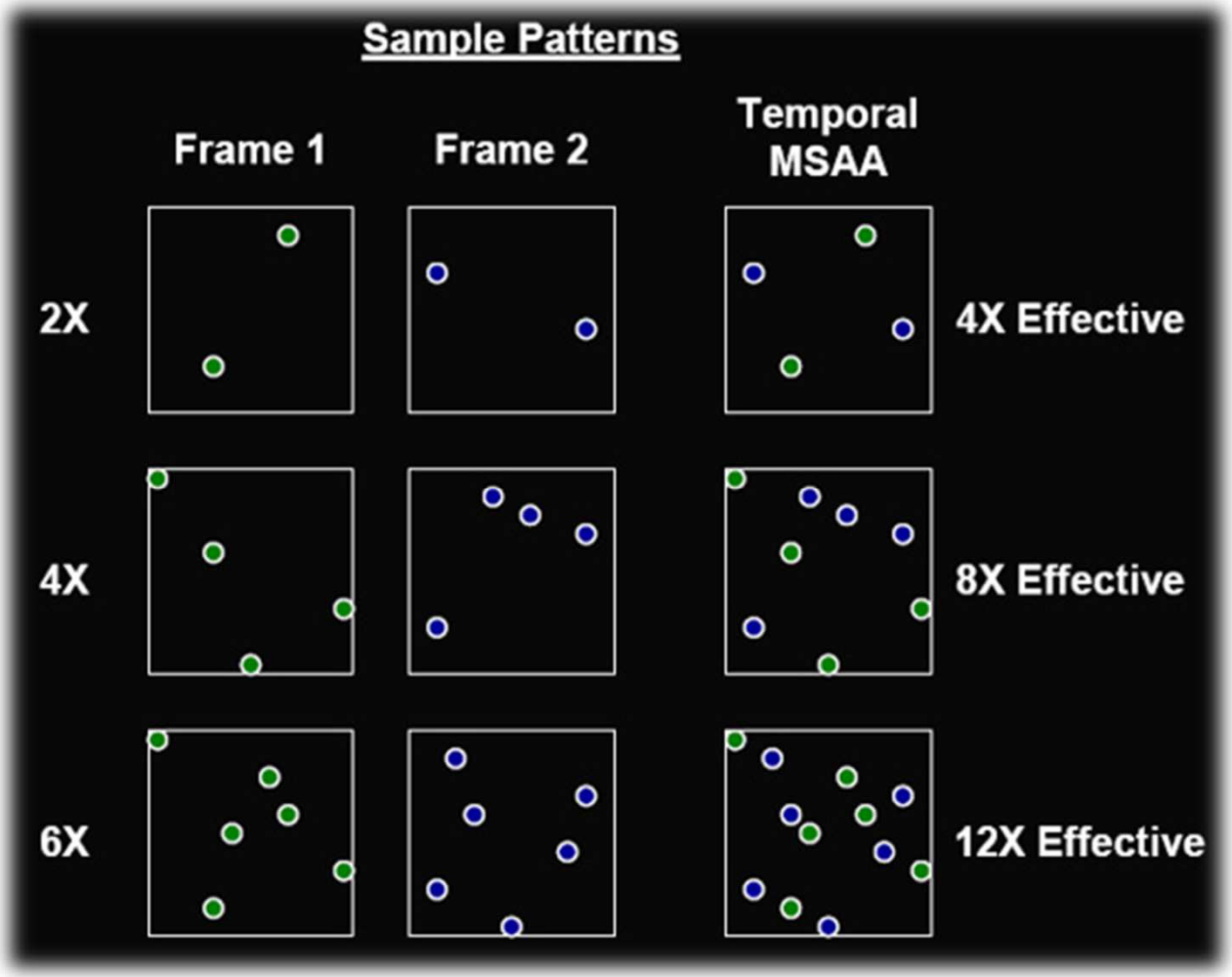
Edge

Geometric sample

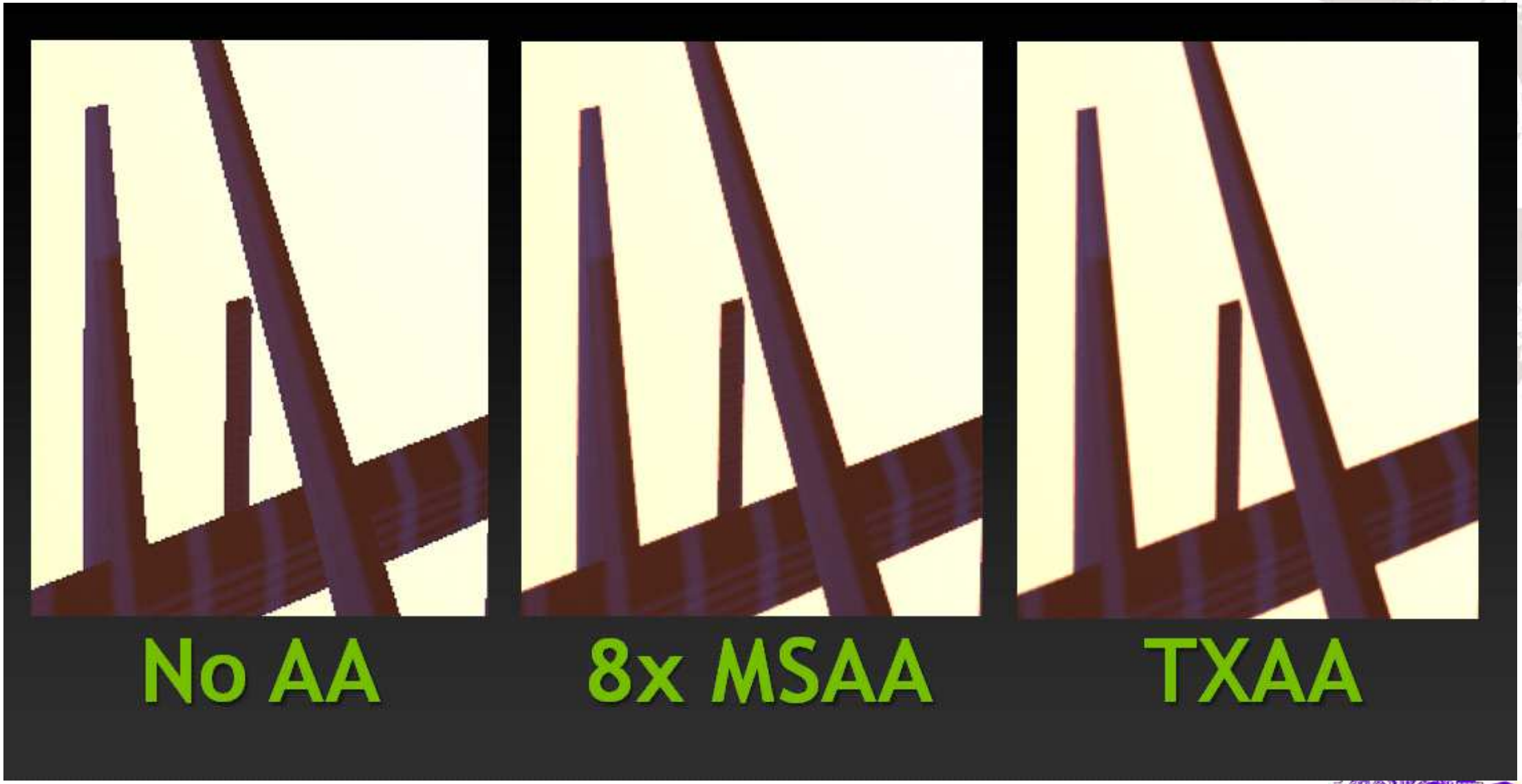


Temporal MSAA (TXAA)

- Use less samples to achieve higher samples results



Temporal MSAA (TXAA)



Temporal MSAA (TXAA)

Temporal MSAA (TXAA)

Q&A