Antialiasing

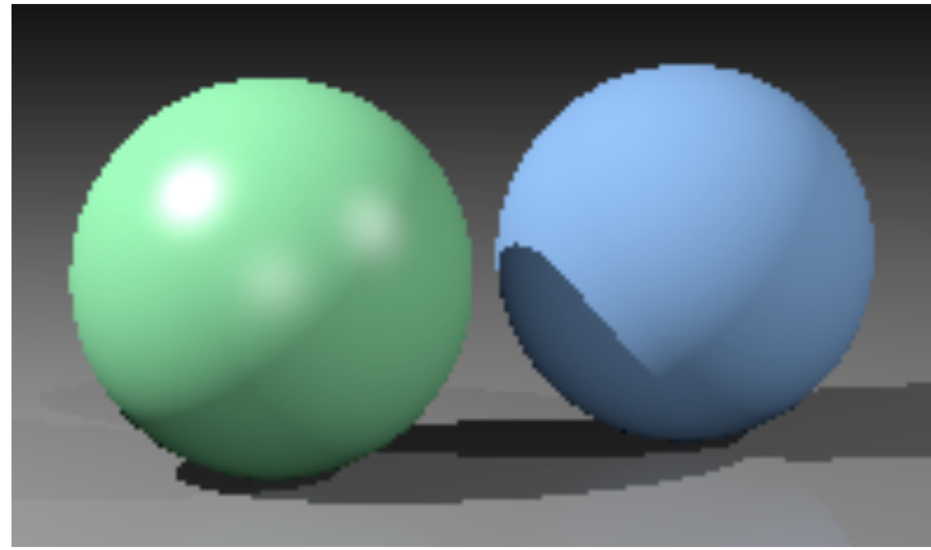
CS5625 Lecture 12

(with previous instructors James/Bala, and some slides borrowed from Kurt Akeley)

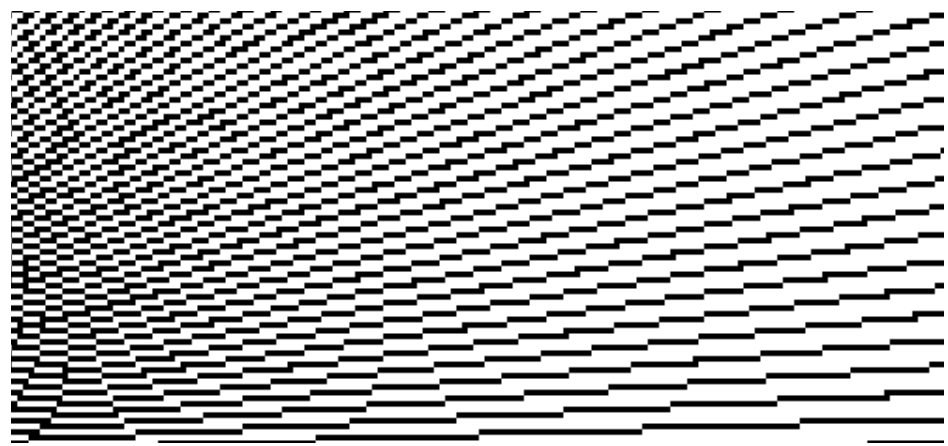
Aliasing

point sampling a
continuous image:

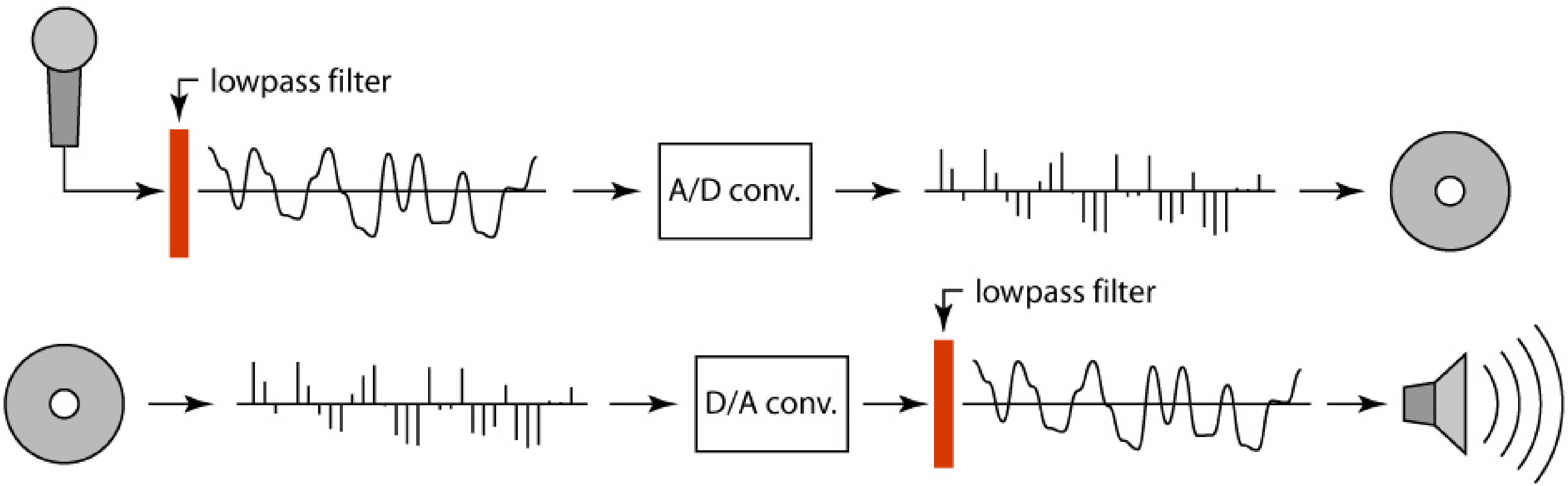
continuous image defined
by ray tracing procedure



continuous image defined
by a bunch of black rectangles

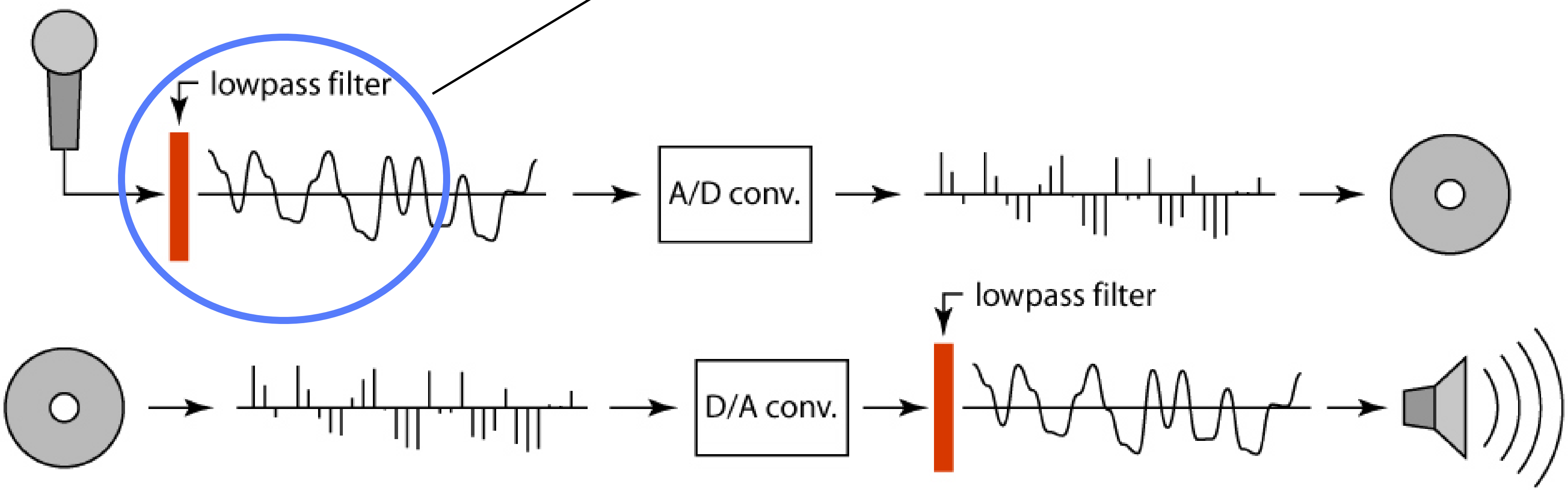


Signal processing view



Signal processing view

we need to remember this step



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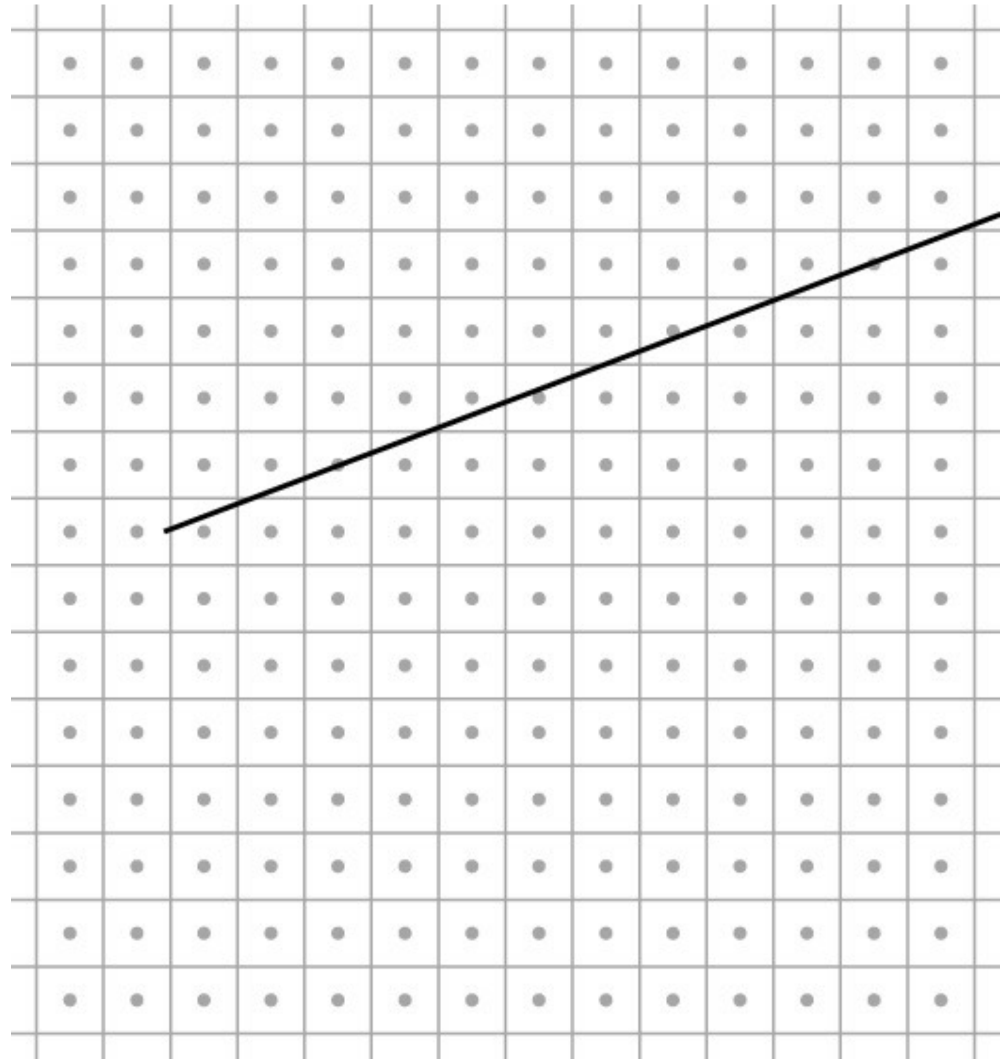
Antialiasing

- A name for techniques to prevent aliasing
- In image generation, we need to filter
  - Convolve continuous image with a sampling filter
  - Simple: average the image over an area (box filtering)
  - Better: weight by a smoother filter
- Methods depend on source of image
  - Rasterization (lines and polygons)
  - Point sampling (e.g. raytracing)
  - Texture mapping

Rasterizing lines

- Define line as a rectangle
- Specify by two endpoints
- Ideal image: black inside, white outside



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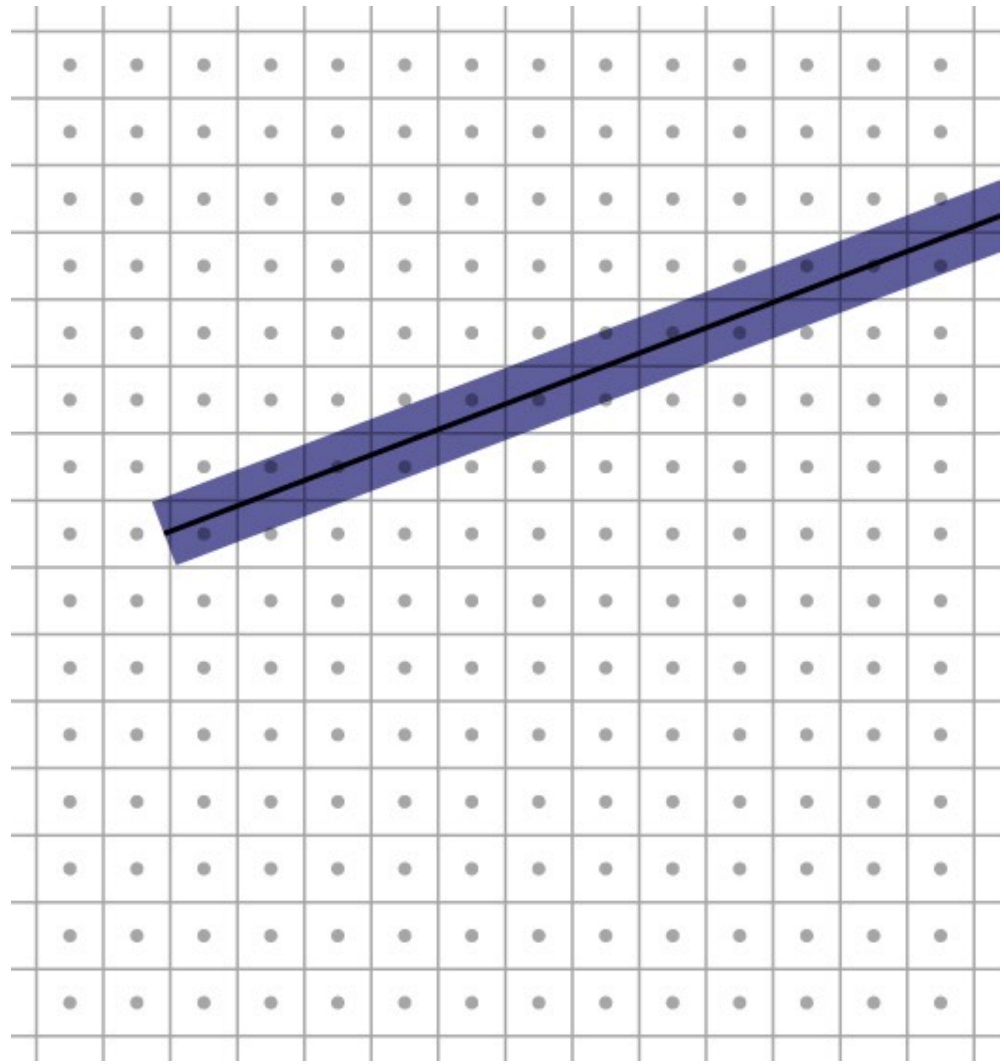
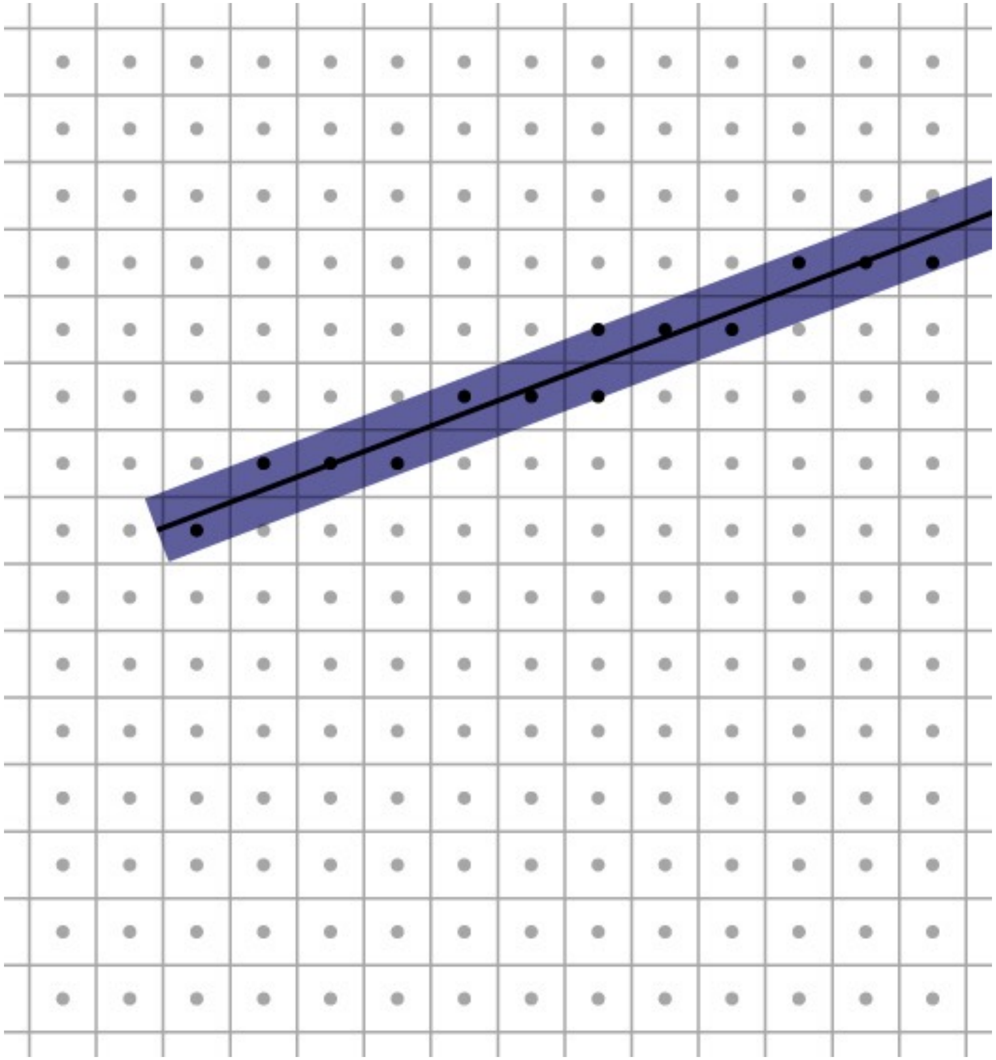


Point sampling

- Approximate rectangle by drawing all pixels whose centers fall within the line
- Problem: all-or-nothing leads to jaggies
  - this is sampling with no filter (aka. point sampling)



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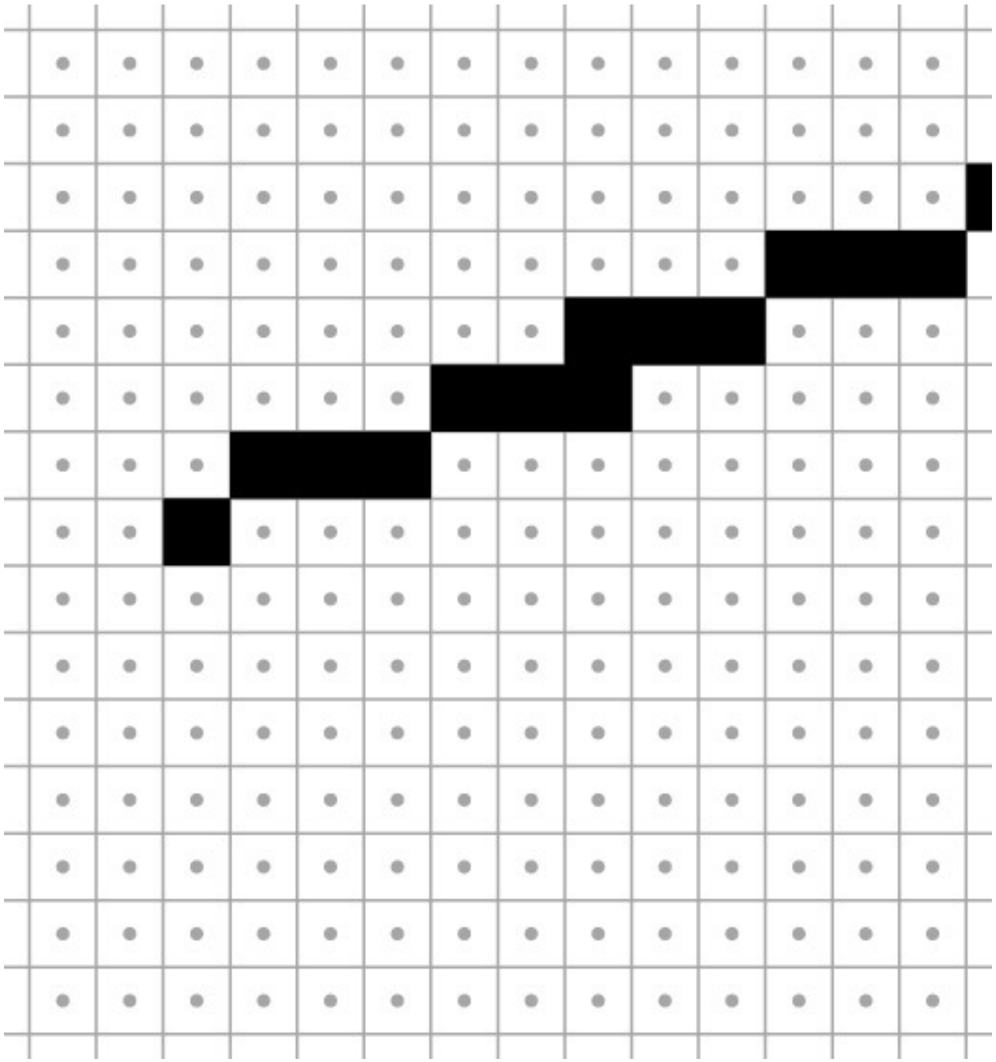

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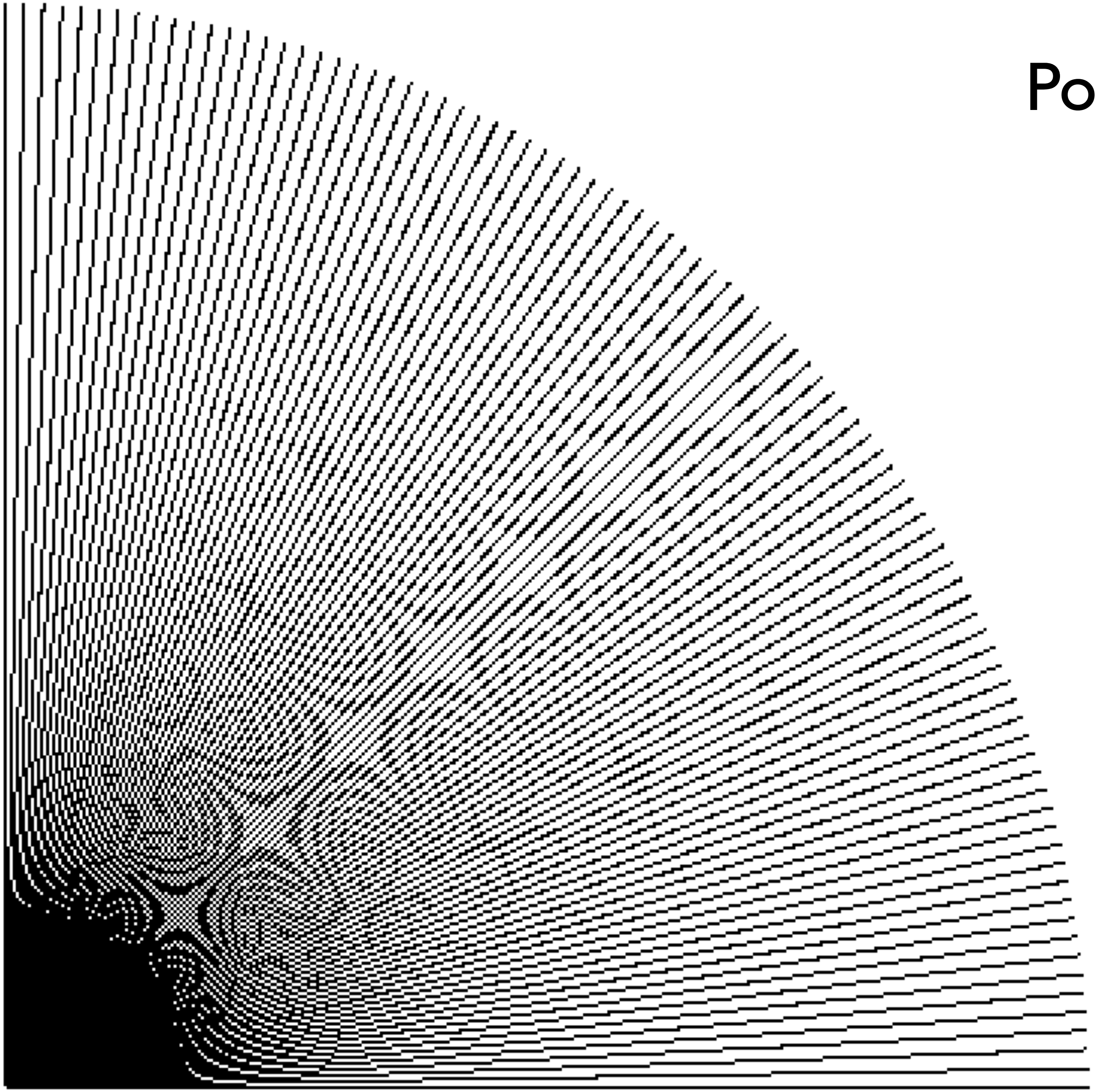
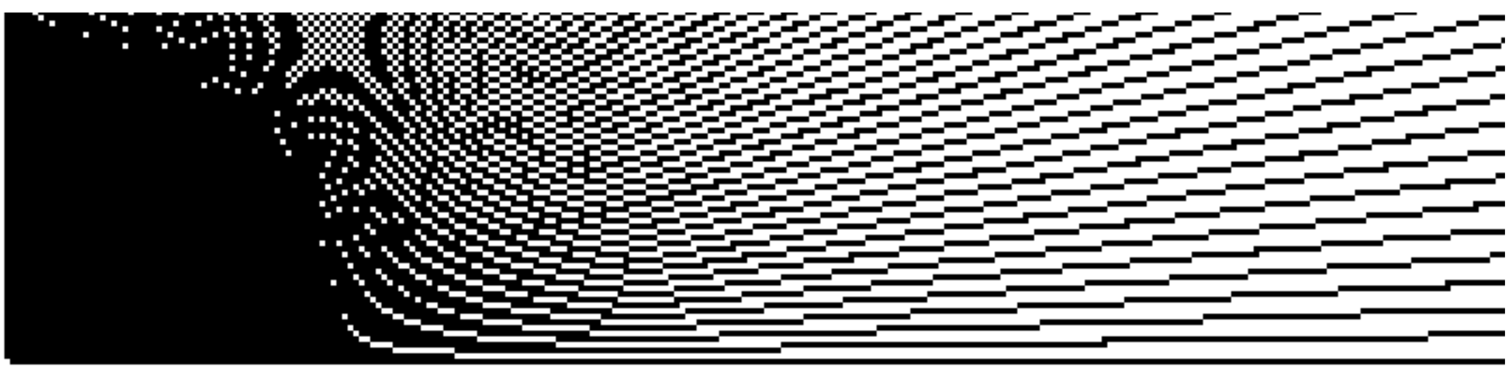


Point sampling in action

Aliasing

- Point sampling is fast and simple
- But the lines have stair steps and variations in width
- This is an aliasing phenomenon
  - Sharp edges of line contain high frequencies
- Introduces features to image that are not supposed to be there!

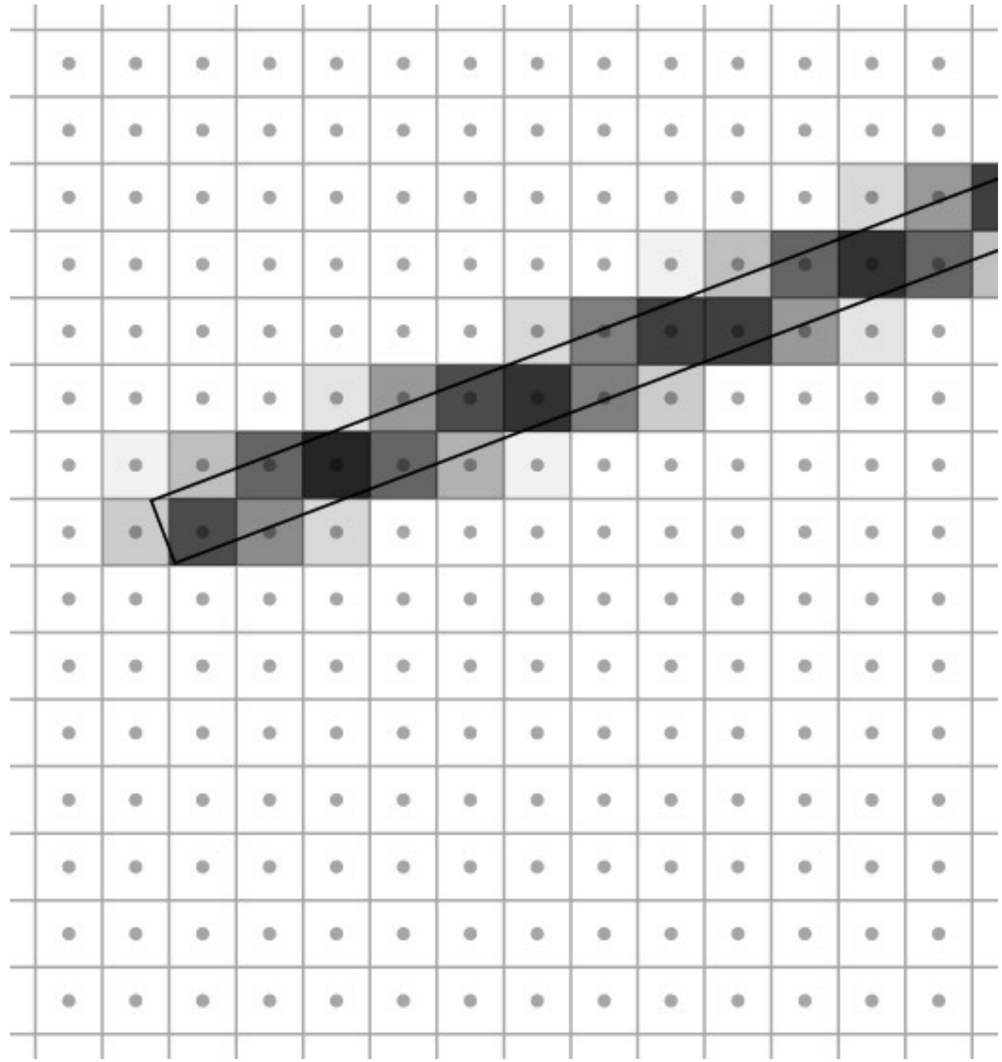


Antialiasing

- Point sampling makes an all-or-nothing choice in each pixel
  - therefore steps are inevitable when the choice changes
  - yet another example where discontinuities are bad
- On bitmap devices this is necessary
  - hence high resolutions required
  - 600+ dpi in laser printers to make aliasing invisible
- On continuous-tone devices we can do better

Antialiasing

- Basic idea: replace "is the image black at the pixel center?" with "how much is pixel covered by black?"
- Replace yes/no question with quantitative question.

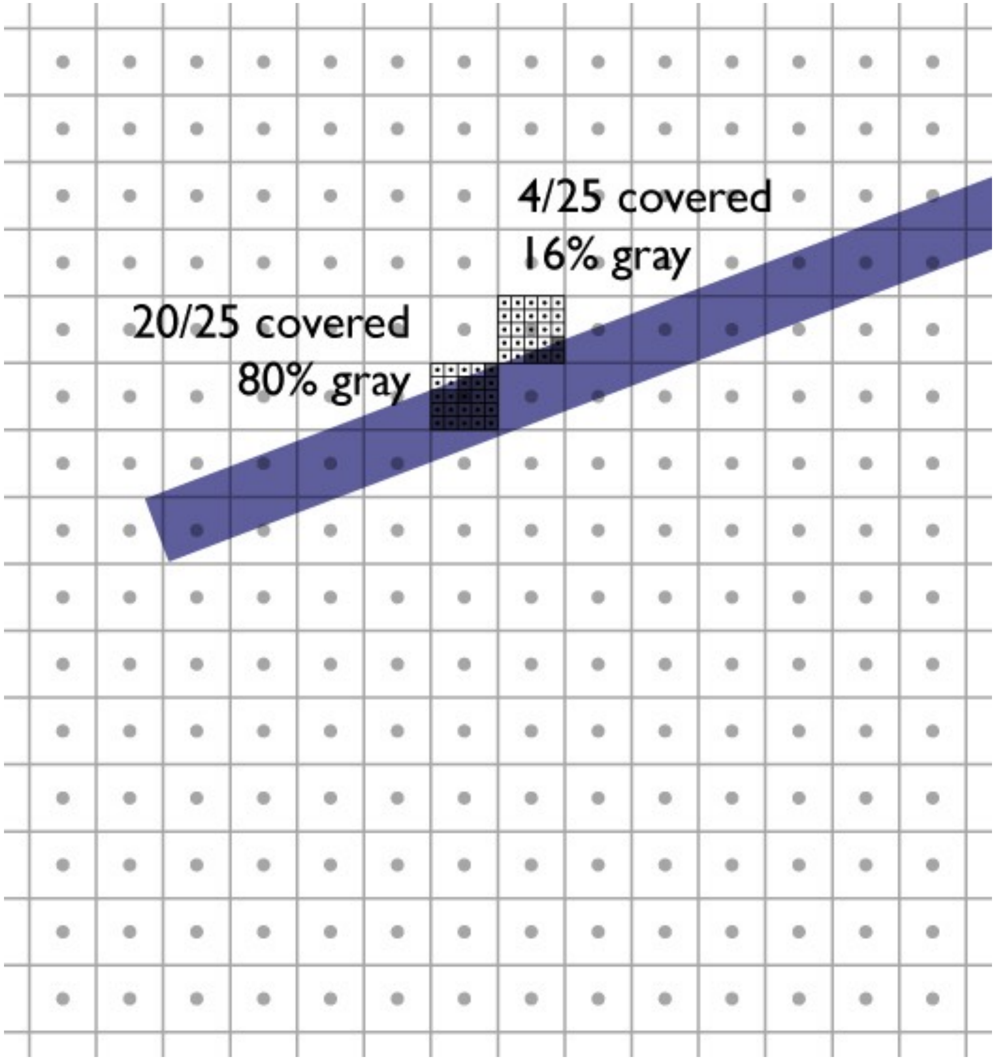


Box filtering

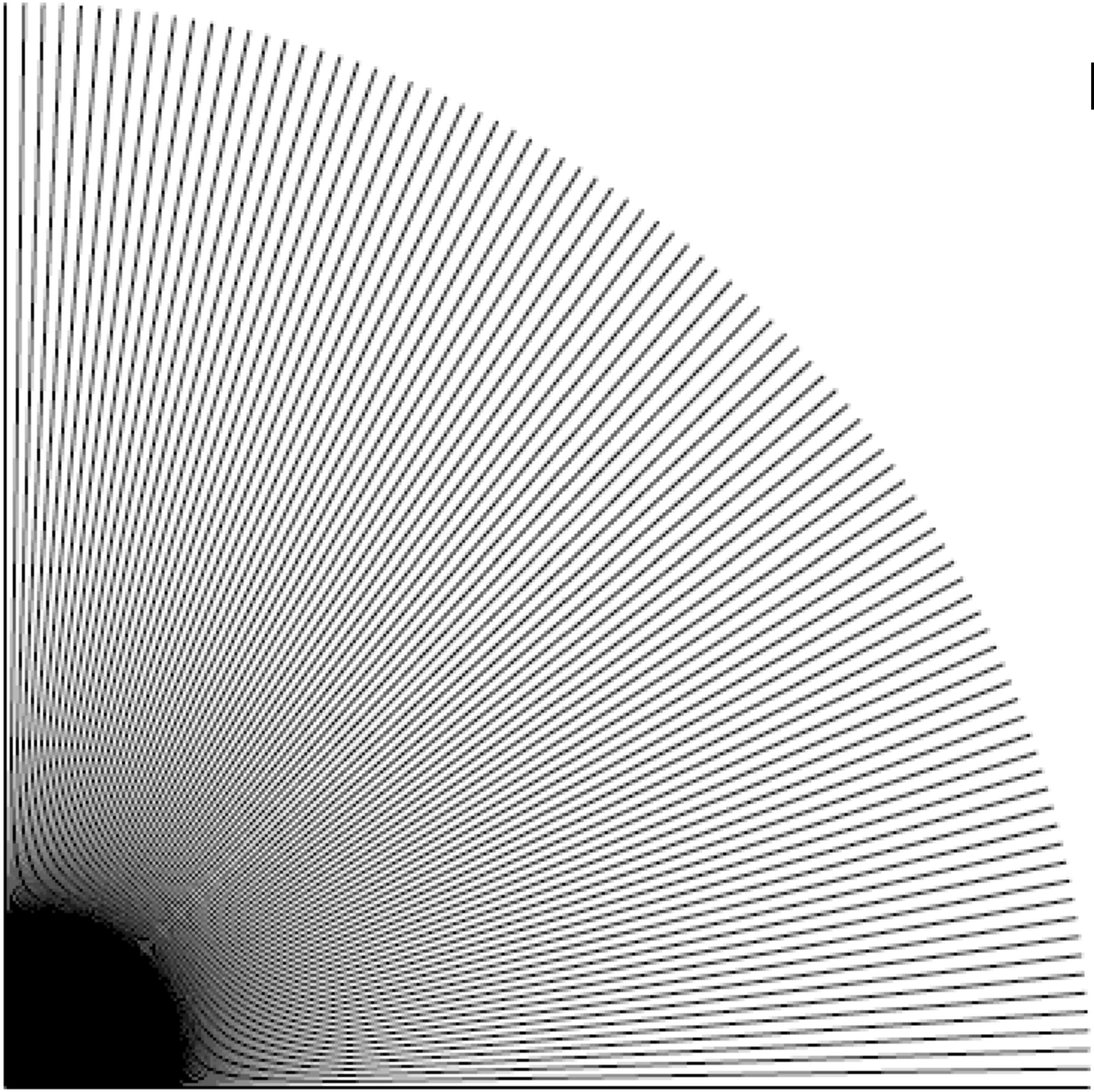
- Pixel intensity is proportional to area of overlap with square pixel area
- Also called "unweighted area averaging"

Box filtering by supersampling

- Compute coverage fraction by counting subpixels
- Simple, accurate
- But slow



Box filtering in action

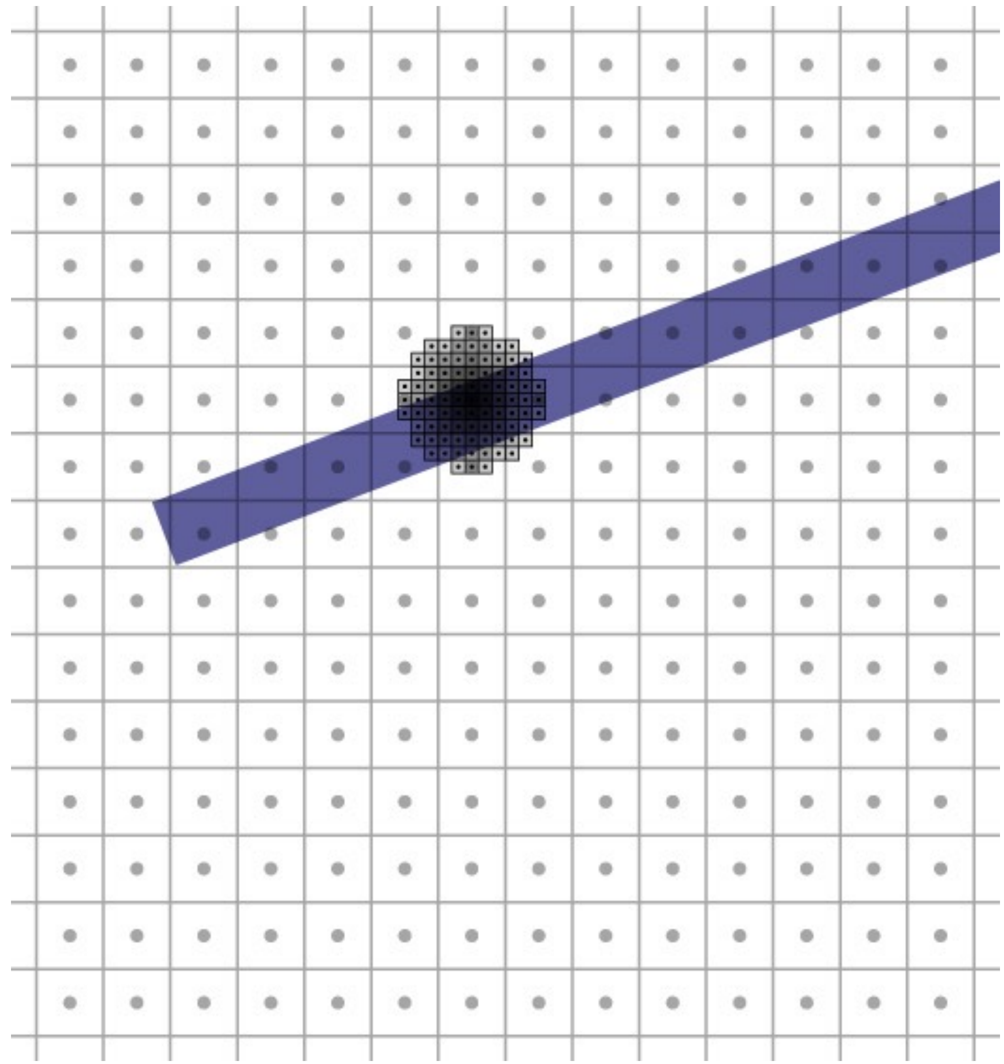


Weighted filtering

- Box filtering problem: treats area near edge same as area near center
  - results in pixel turning on "too abruptly"
- Alternative: weight area by a smooth function
  - unweighted averaging corresponds to using a box function
  - a gaussian is a popular choice of smooth filter
  - important property: normalization (unit integral)

Weighted filtering by supersampling

- Compute filtering integral by summing filter values for covered subpixels
- Simple, accurate
- But really slow



Weighted filtering by supersampling

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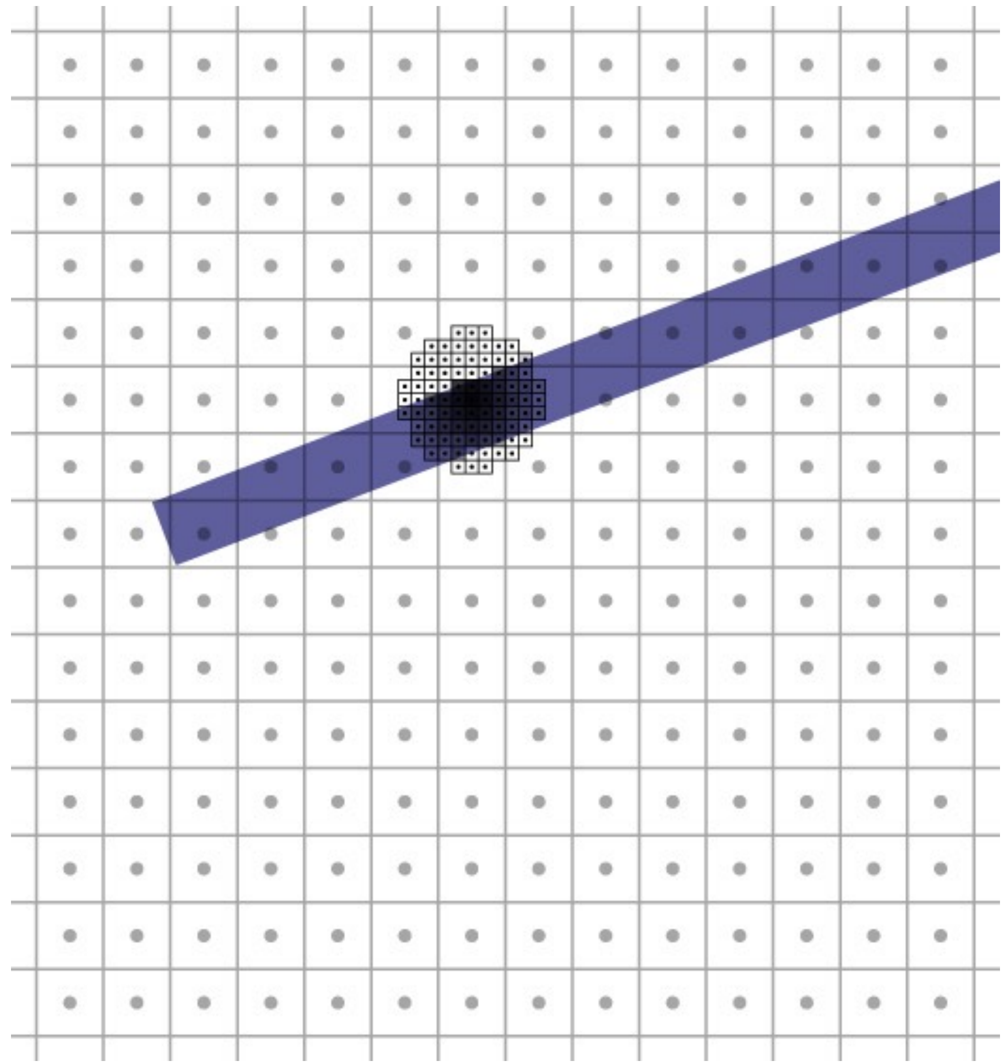
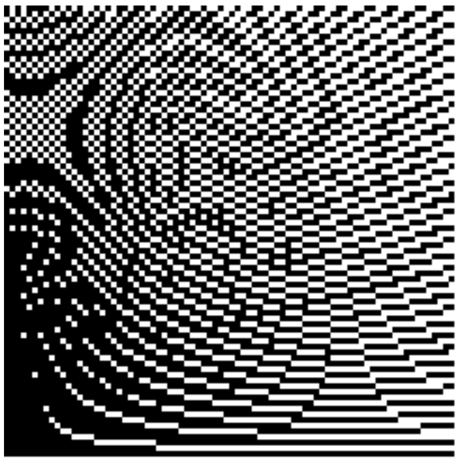
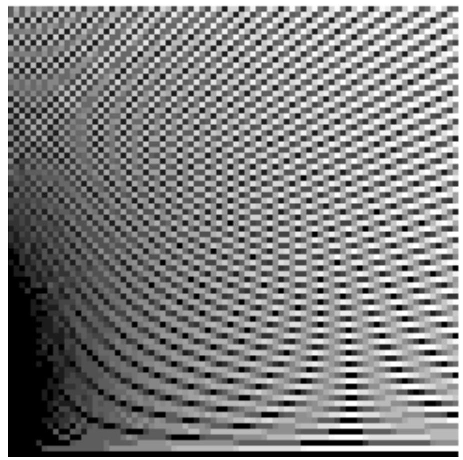


Gaussian filtering in action

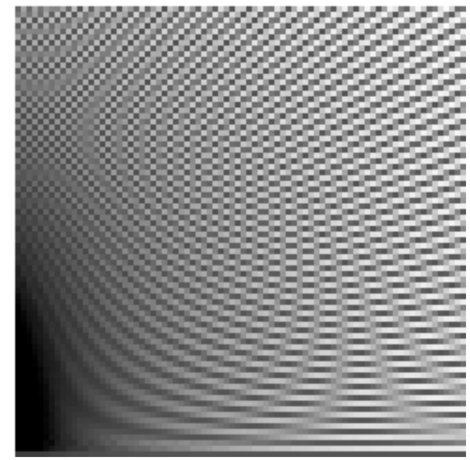
Filter comparison



Point sampling



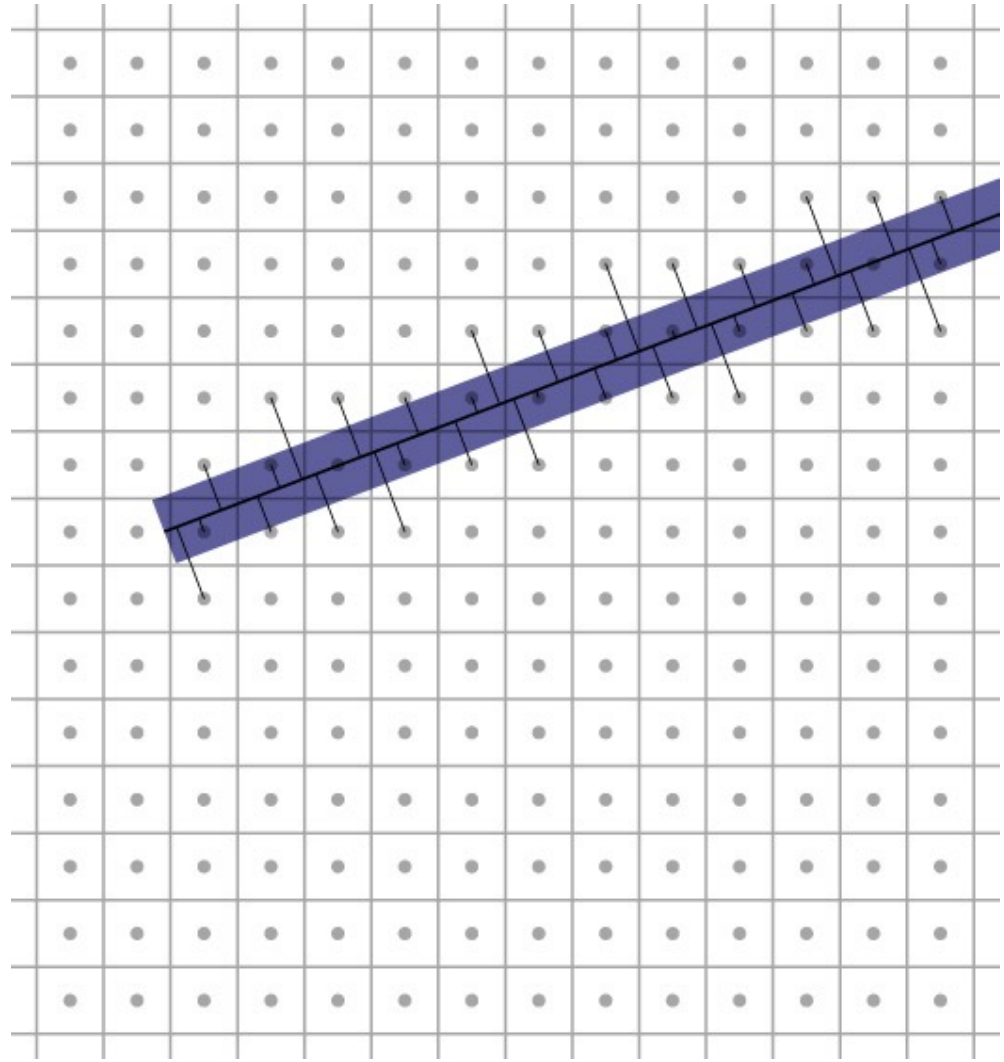
Box filtering



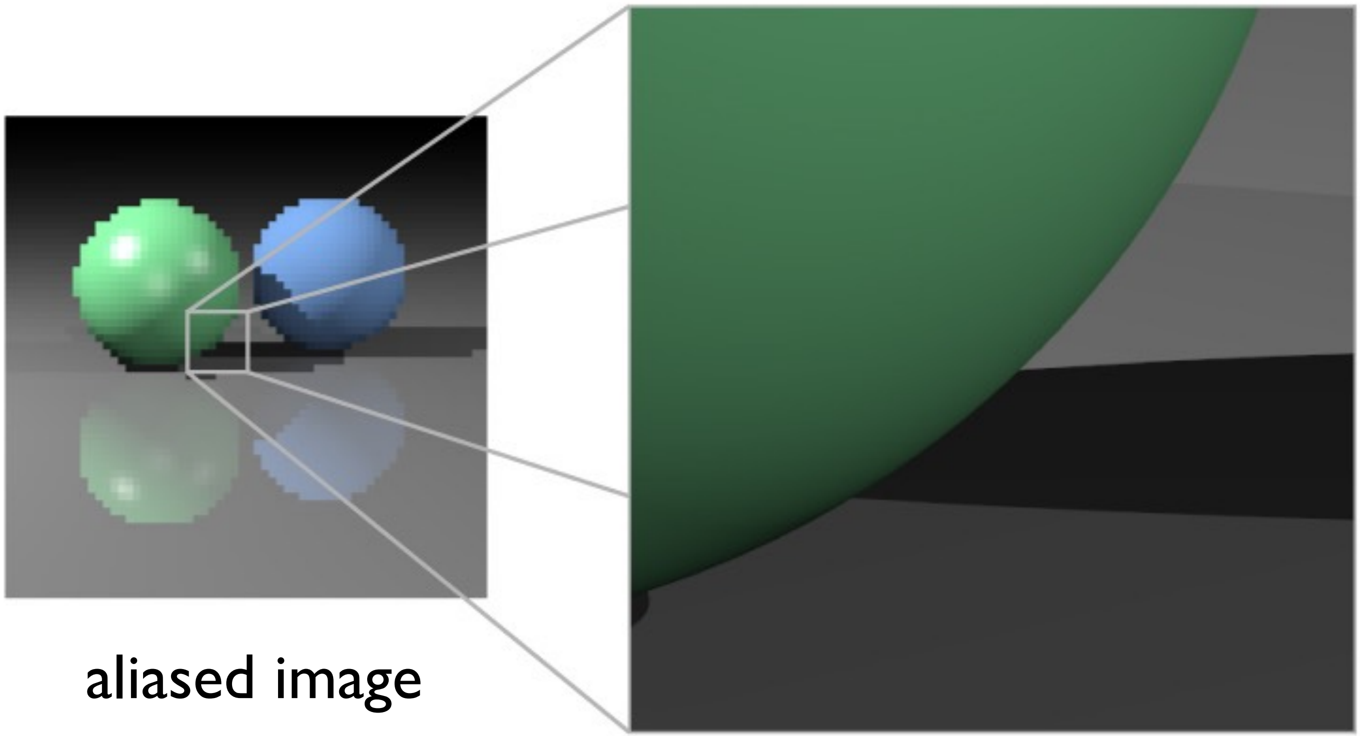
Gaussian filtering

More efficient antialiased lines

- Filter integral is the same for pixels the same distance from the center line
- Just look up in precomputed table based on distance
  - Gupta-Sproull
- Some additional details at ends…

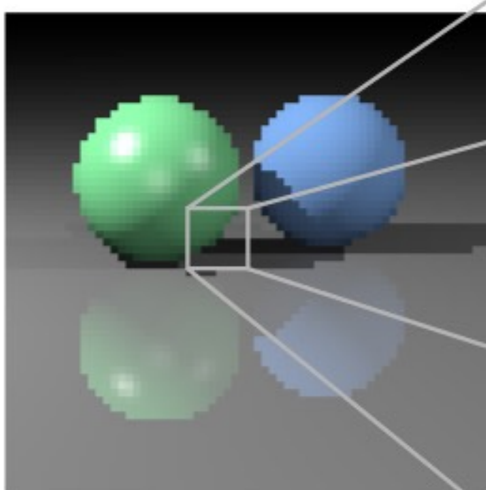


Antialiasing in ray tracing

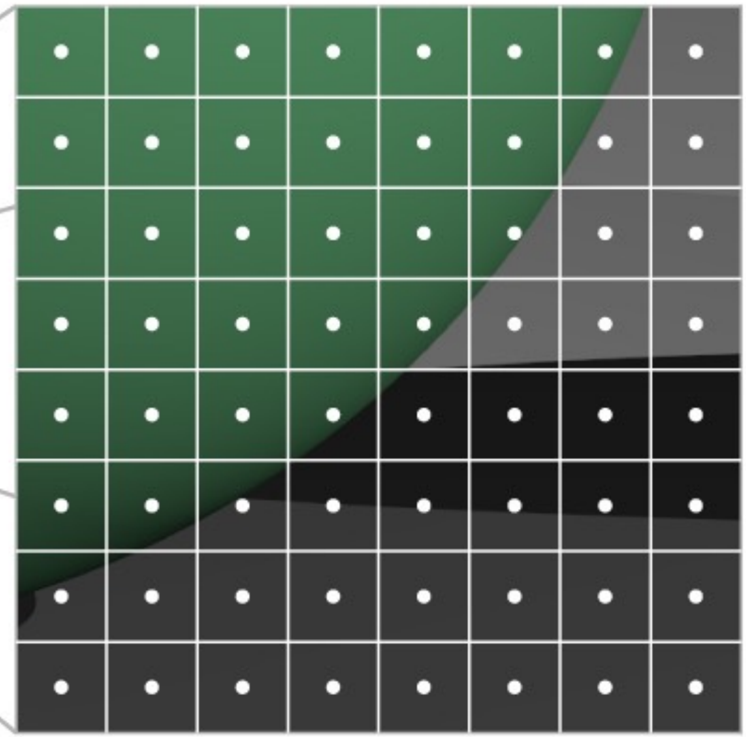


aliased image

Antialiasing in ray tracing

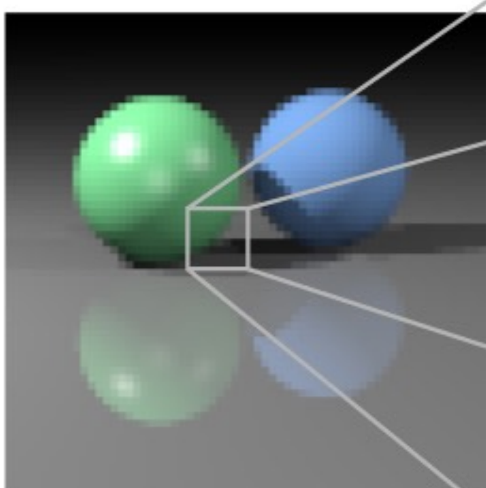


aliased image

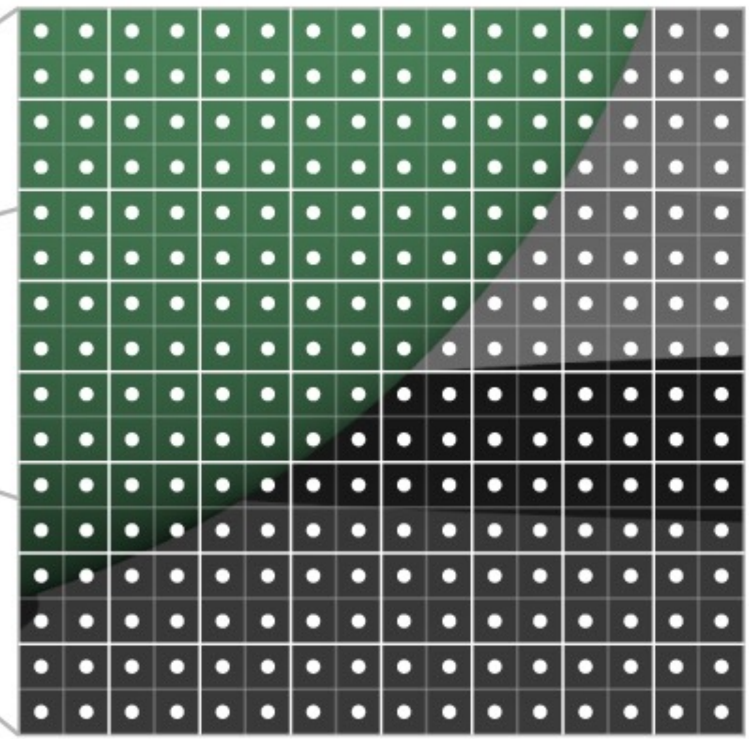


one sample per pixel

Antialiasing in ray tracing



antialiased image



four samples per pixel

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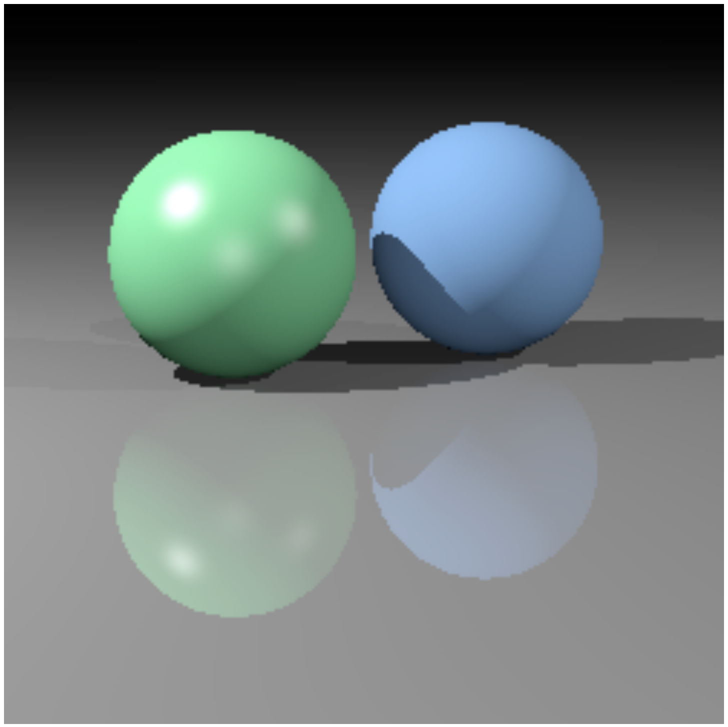
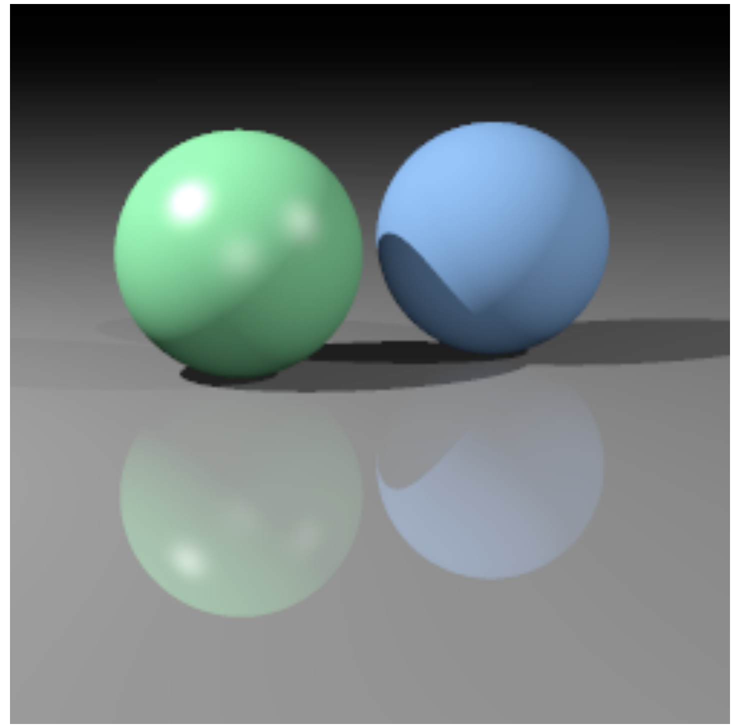
Antialiasing in ray tracing



one sample/pixel



9 samples/pixel

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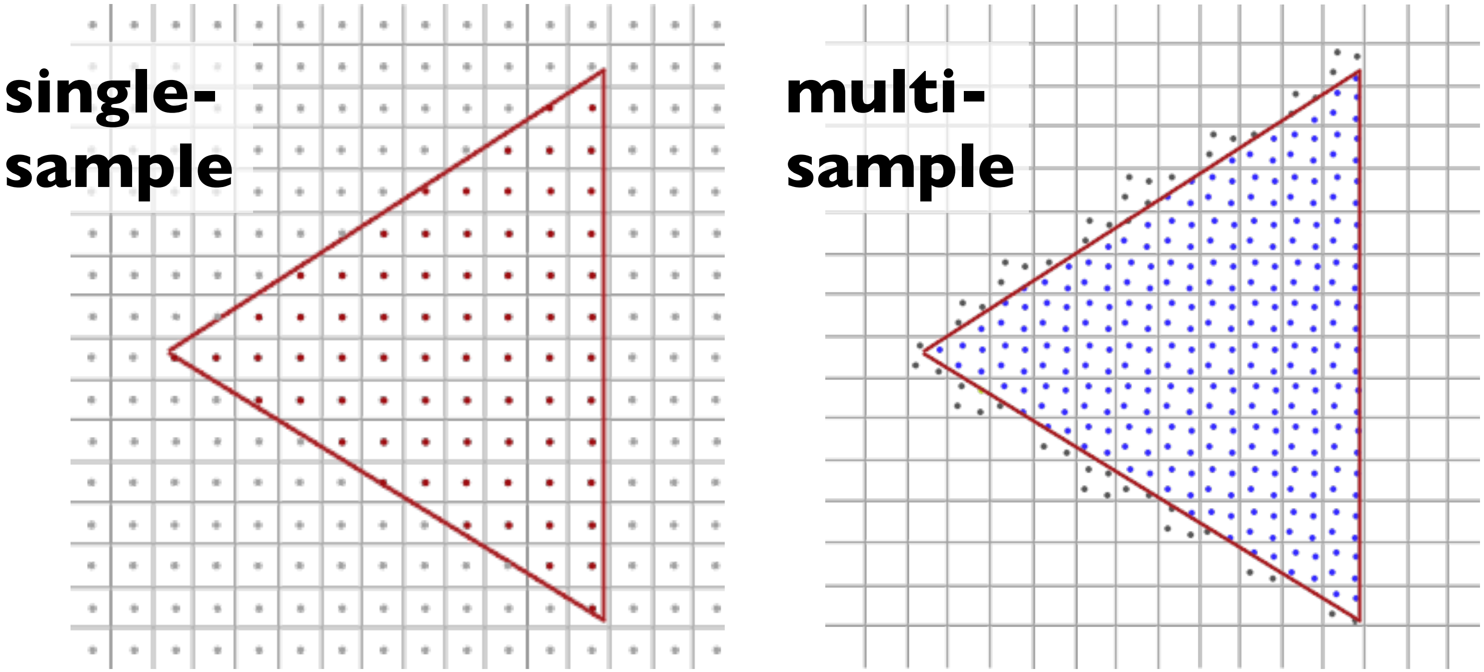
Supersampling vs. multisampling

- Supersampling is terribly expensive
- GPUs use an approximation called *multisampling*
  - Compute one shading value per pixel
  - Store it at many subpixel samples, each with its own depth

Multisample rasterization

- Each fragment carries several (color,depth) samples
  - shading is computed per-fragment
  - depth test is resolved per-sample
  - final color is average of sample colors



[http://www.learnopengl.com]

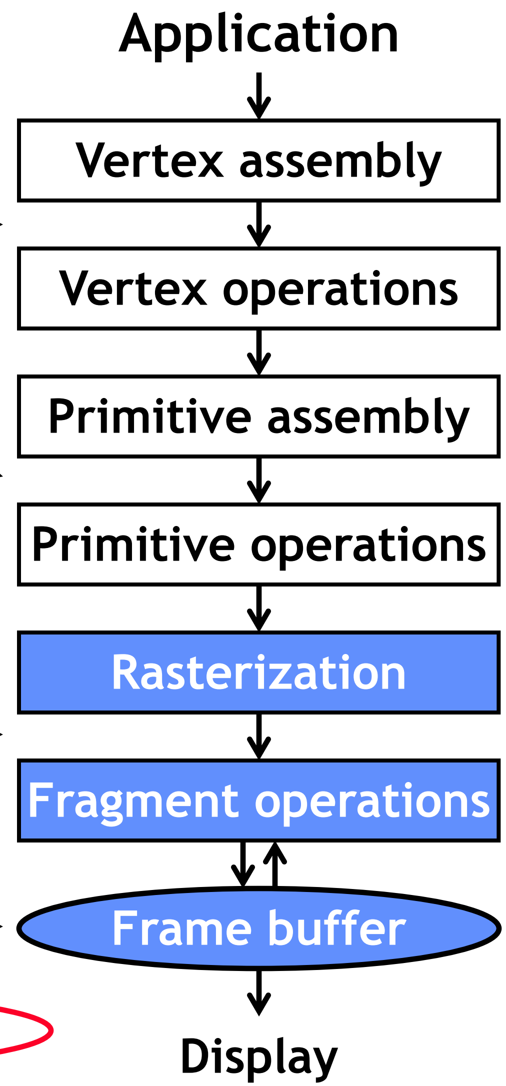
Multisample implementation (n samples)

```
struct {
  float x,y,z,w;
  float r,g,b,a;
} vertex;

struct {
  vertex v0,v1,v2
} triangle;

struct {
  short x,y;
  bool mask[n];
  float depth[n];
  float r,g,b,a;
} fragment;

struct {
  short R,G,B;
  int depth[n];
  byte r[n],g[n],b[n];
} pixel;
```



Point sampling at multisample locations sets mask and computes depths. Color is taken from center-most sample.

Fragment samples are depth-merged into the multisample buffer, then filtered to the color buffer.

Multisample rasterization operations

Fragment selection

- Identify pixels for which fragments are to be generated
- New: generate fragment if *any* sample is within the primitive
  - Requires tiled sampling, rather than point sampling
  - Generates more fragments

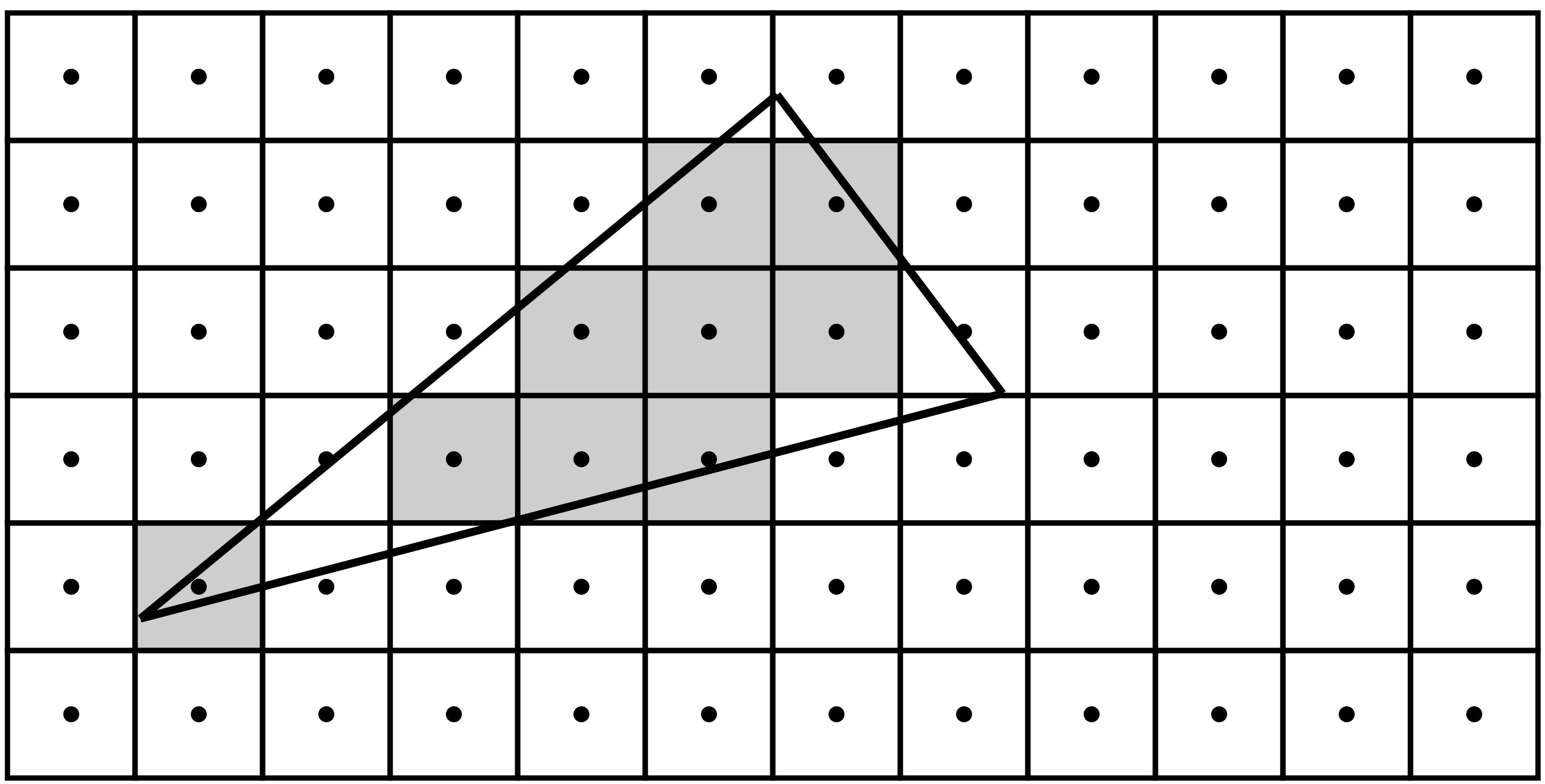
Attribute assignment

- Assign attribute values to each fragment
- Sample color at the center of the pixel (as before)
- New: compute the Boolean per-sample coverage mask
  - True if-and-only-if the sample is within the primitive
- New: compute depth values for each sample location

Point-sampled fragment selection

Generate fragment if pixel center is inside triangle

Implements point-sampled aliased rasterization



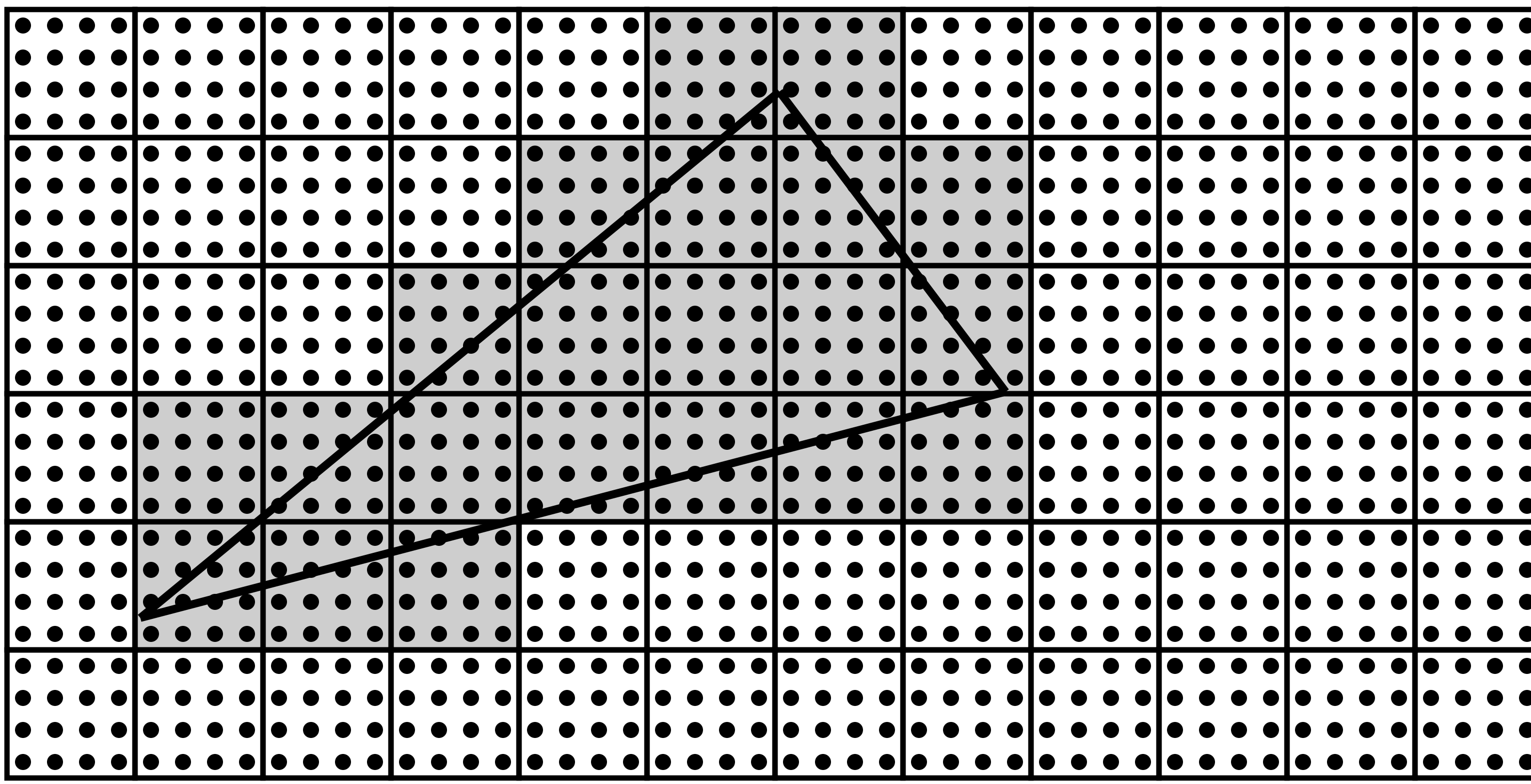
9 fragments generated

Tiled fragment selection

Generate fragment if unit square intersects triangle

Implements multisample rasterizations

- 4x4 sample pattern with unit-square filter extent



21 fragments generated