Computer Graphics

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Outline

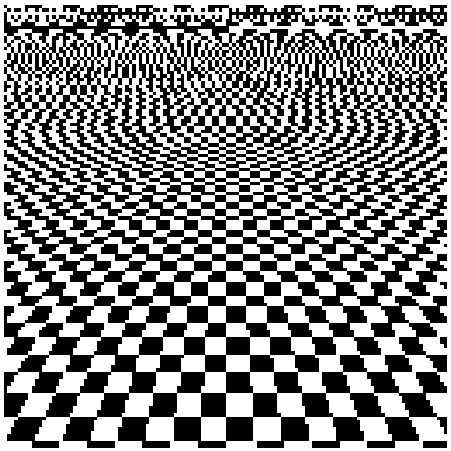
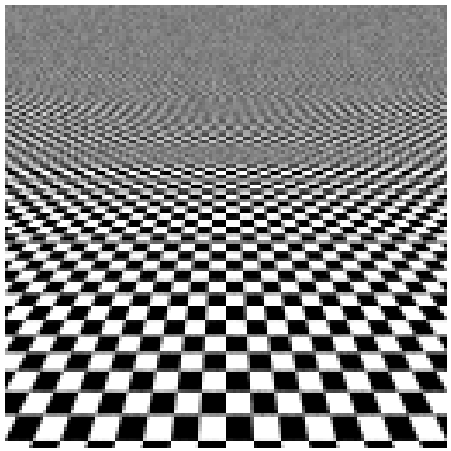
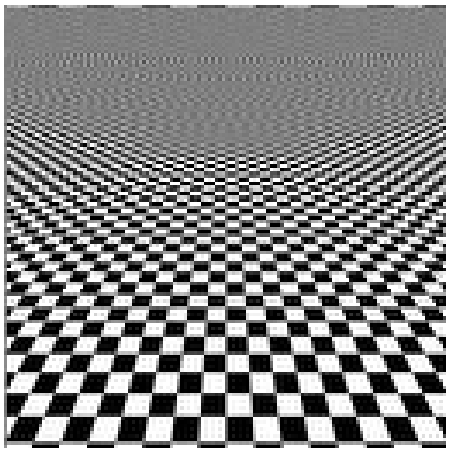
1 Anti-Aliasing; §6-15

Antialiasing

- In spite of all efforts lines can still have the “stair-case” effect, due to
- This is the visual analogue of **undersampling** of an acoustic signal: undersampling prevents unique reconstruction of the original acoustic signal, since there will be **alias** signals will have the same pattern of samples
- Thus we call the of lines aliases
- Our efforts at avoiding this problem are called **antialiasing**
- Most obvious solution: decrease pixel size – but this makes demands : bigger framebuffer needed; more data flow

Antialiasing

A poorly rendered chessboard (left) and two improvements on it (centre, right)

Antialiasing Solutions

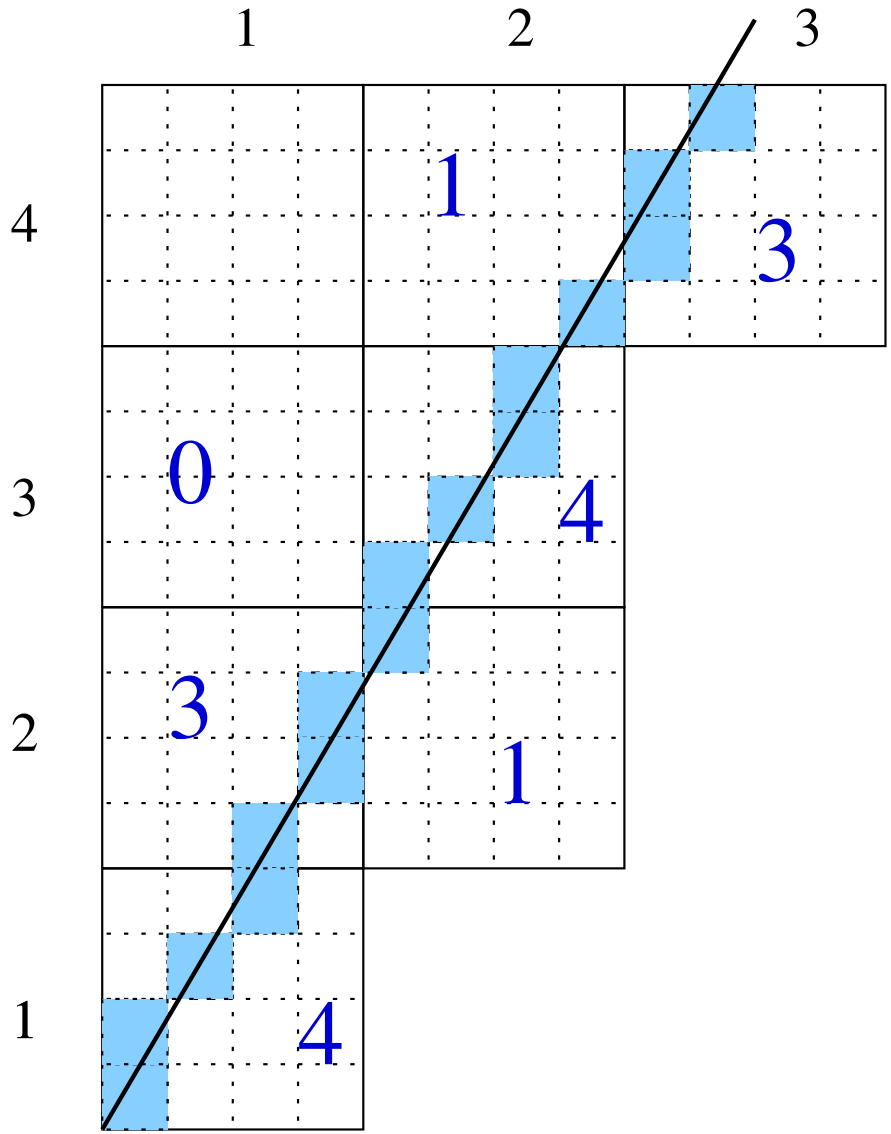
- Decreasing Pixel-Size:
  - Increasing screen resolution leads to difficulties in maintaining 60Hz refresh rate
  - It doesn't make the problem go away since representing objects accurately requires arbitrarily small sampling intervals
- Modify pixel intensity:
  - By varying intensity of pixel in proportion to how close it is to line we can smooth out edges
  - Used in one form or another by almost all antialiasing techniques

Antialiasing Solutions

- Supersampling:
  - Divide each pixel into smaller grid, count number of the smaller sample points and use this as an indicator of intensity
  - Note: we're not
- Area sampling:
  - Measure area of overlap between pixel and object to be drawn
  - More overlap means greater intensity

Supersampling

- Divide each pixel into smaller grid of sub-pixels and count number of smaller sample point crossings
- Use Bresenham's alg on sub-pixels to count these crossings
- n sub-divisions mean at most n sub-pixel crossings mean $n+1$ intensities $(0, \ldots, n)$ needed
- Display intensity is proportional to this figure



Supersampling

- Deficiency of previous model is that lines when drawn don't have 0
- Width of a line is *ca.* 1 pixel
- So from display point of view a line is really a polygon of thickness 1 pixel...
- ...and sub-pixel counting should be with respect to inclusion within this polygon
- This means that n sub-divisions gives rise to counts of $[0 \ldots n^2]$ so we more intensities

Supersampling

- Not all subpixels are created equal: if a line (non-zero thickness now) goes through the centre subpixel of subdivided pixel then this subpixel should count for more than a line that barely cuts through a corner subpixel

1	2	1
2	4	2
1	2	1

Sum of subpixel weights is 16 so each subpixel counts for $\frac{1}{16}$th multiplied by its weight

- Supersampling has side benefit of "filling in gaps" to compensate for sampling: using Bresenham LD alg. both lines below are condemned to use same no. of pixels yet diagonal is $\sqrt{2}$ times longer...
- Some advantages...

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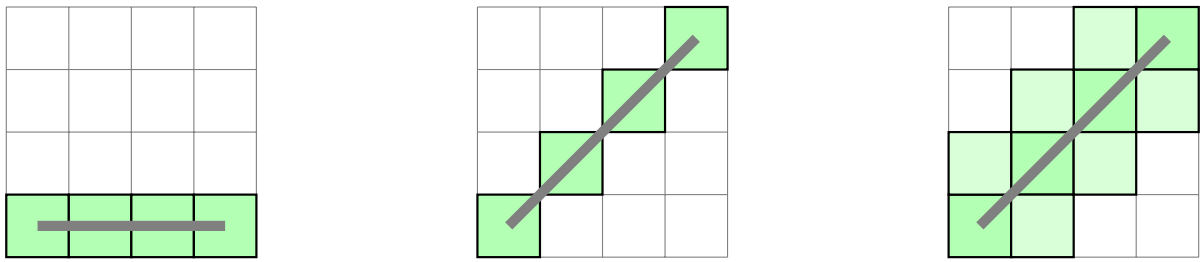

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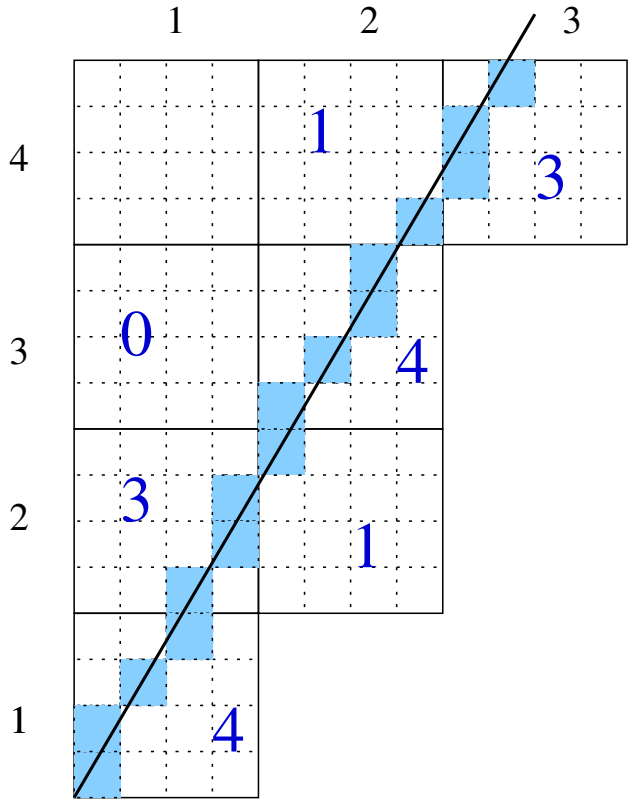
Advantages of Supersampling

- When a line is considered to have non-zero width additional pixels can be included (with low intensity); for example, pixel (1,3) below might be included with low intensity (instead of 0 shown below)



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- Also, with a colour display a line that crosses several colour regions we can  subpixel intensities to get a blended colour
- For example, given a blue "line" that crosses 9 subpixels and 5 background green pixels, of its 4x4 subpixels we can average the colour to be $\frac{9\times\text{blue}+5\times\text{green}}{16}$
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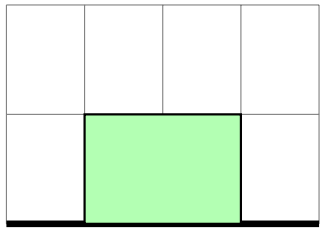
Disadvantages of Supersampling

- Price to pay for treating a line as a polygon is that "subpixel within polygon" test is more expensive
- Further, the fundamental, *mathematical line*, associated with polygon is not always in same position:
  - With a 45° line the enclosing polygon is symmetric about the *mathematical line*
  - With a horizontal line (or vertical line) the polygon lies all above (to right of) line: 
- For lines where $|m| < 1$ the mathematical line should be positioned "closer" to the lower polygon border; vice versa for $|m| > 1$lines

Hardware Solutions

- **Pixel phasing**: some hardware systems (CRT) have ability to pinpoint sub-pixel location
- A full pixel still gets drawn but, as needed, the pixel can be shifted closer to the line path
- Pixel phasing systems were designed so that electron beam can be shifted by, say, $\frac{1}{4}$, $\frac{1}{2}$ or $\frac{3}{4}$ of a pixel
- Pixel phasing appears to be used in CRT (cathode ray tube) systems only
- Still more elaborate systems can adjust the **size** of the pixel drawn, as needed

Area Sampling

- The alternative to supersampling, **area sampling**, is just an extension of a previous method
- Measure overlap of pixel and polygon that, maybe, represents a line
- Assign intensity of pixel according to amount of overlap

OpenGL Antialiasing Functions

- We instruct OpenGL to perform antialiasing with the function `glEnable()` and one, or more of

```
glEnable(GL_POINT_SMOOTH);
glEnable(GL_LINE_SMOOTH);
glEnable(GL_POLYGON_SMOOTH);
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