Aliasing and Anti-Aliasing

- **Aliasing** is caused by taking samples at too low a frequency
- Red sinusoid is sampled regularly (blue squares)
- Reconstructing a curve through the samples, gives the wrong frequency (blue)

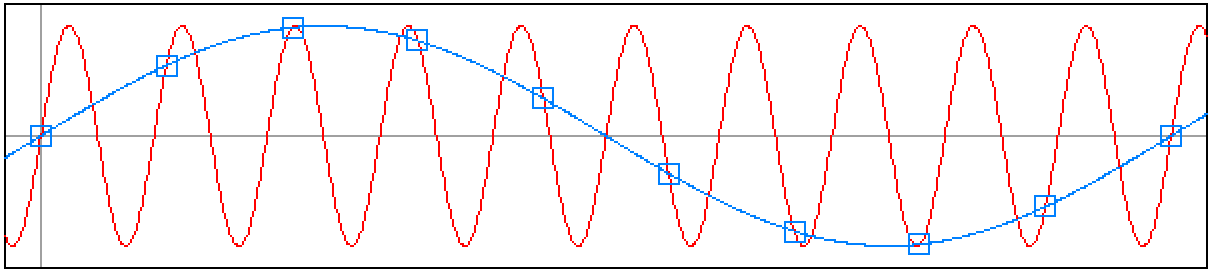


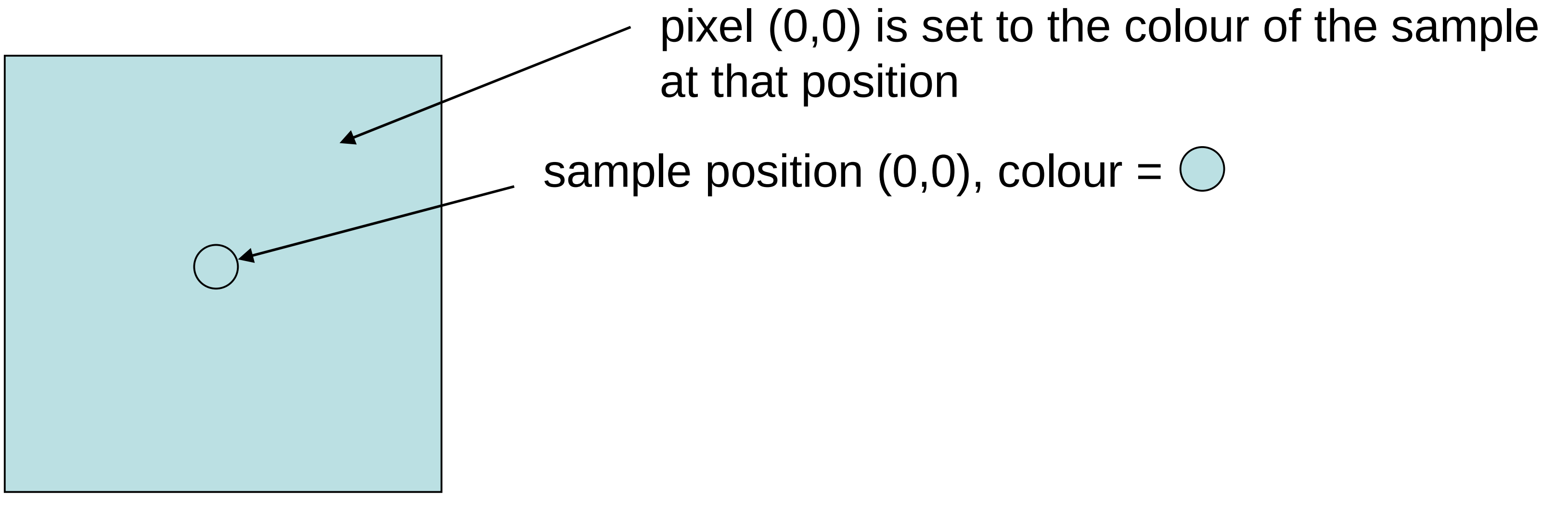
image from wikipedia

Nyquist rate

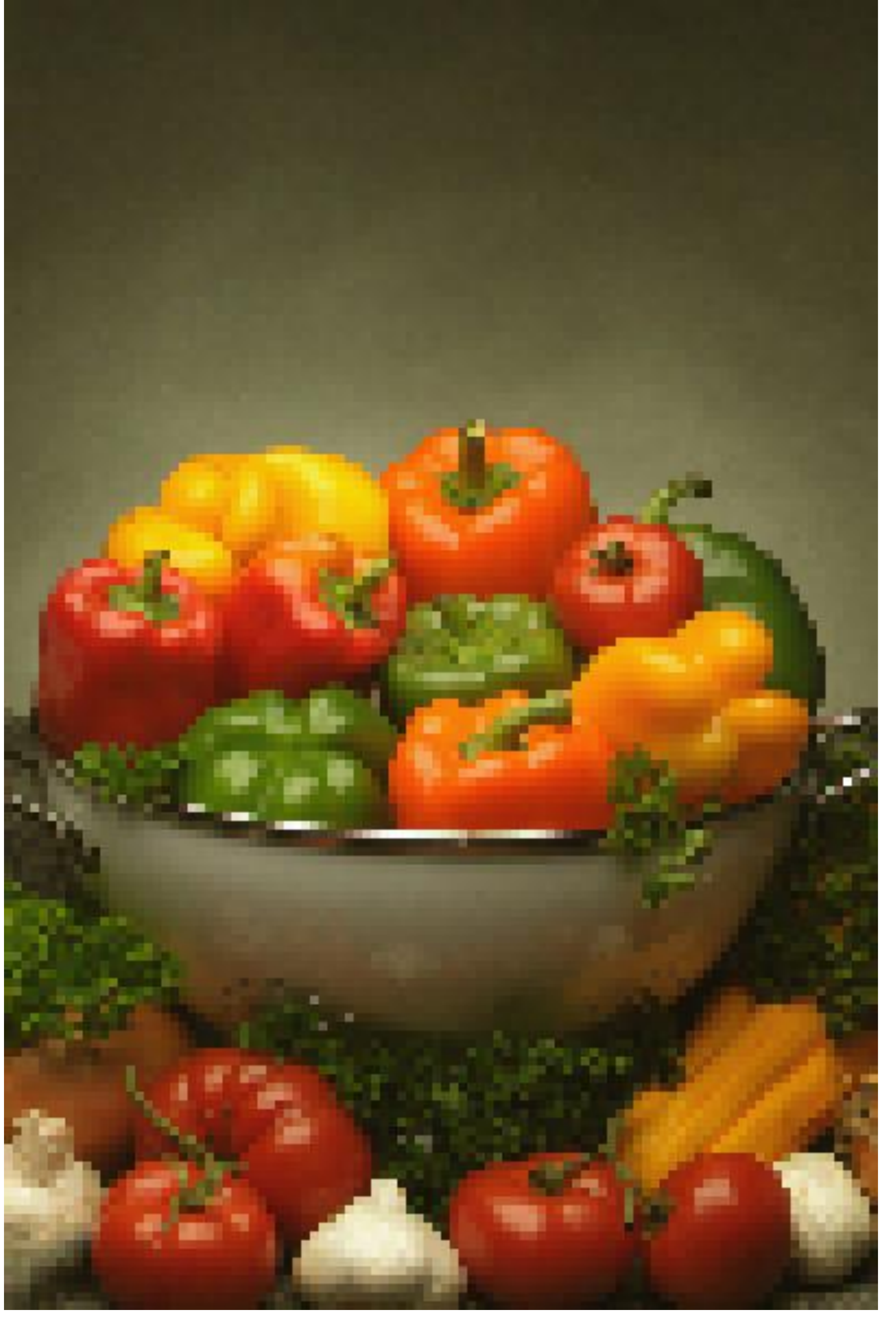
- To reconstruct the signal correctly, sample above the **Nyquist rate**
- If the frequency of the signal is f, samples must be taken at 2f or higher
- Higher rates, ensure more accurate reconstruction

Graphics and aliasing

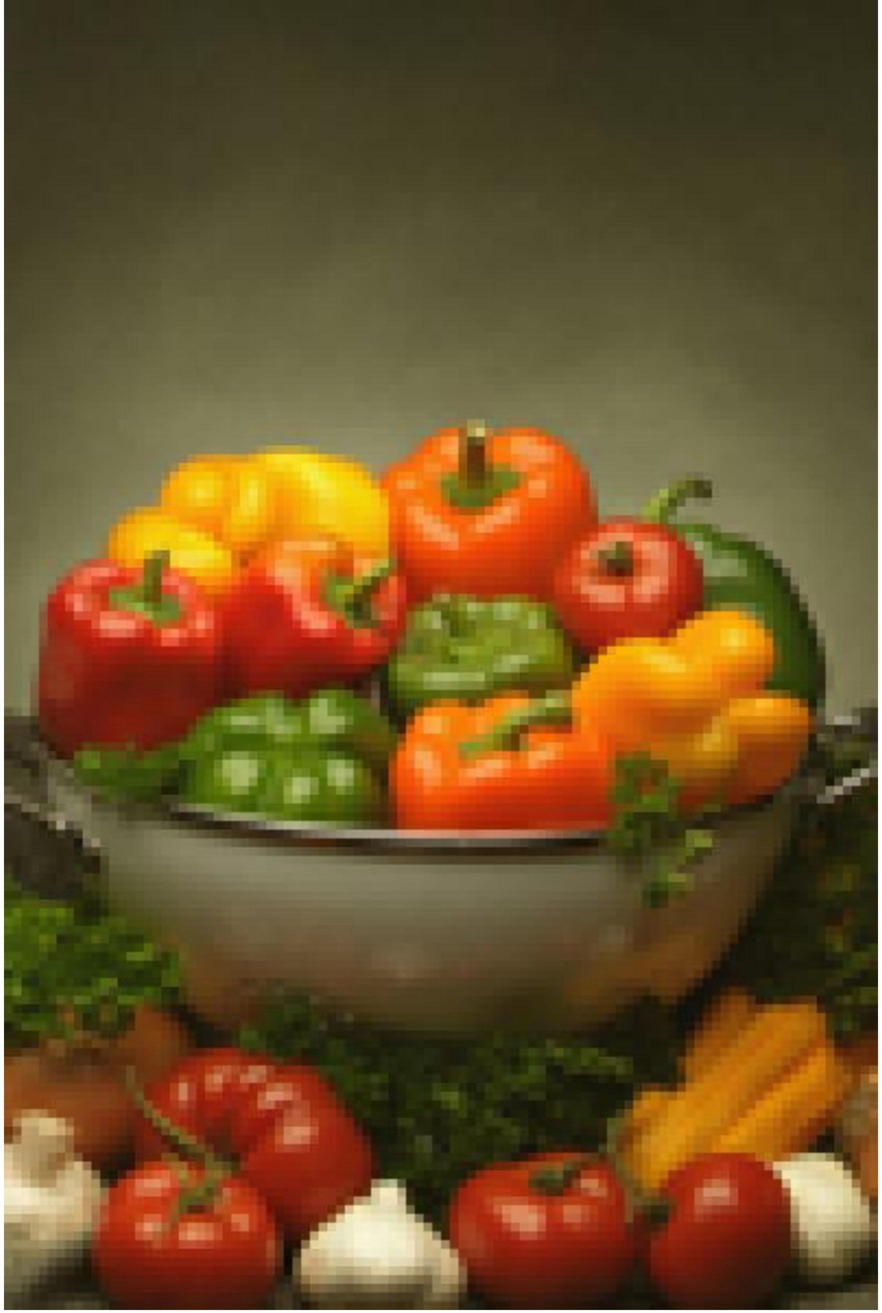
- Images are digital representations of continuous space (see first lecture)
- Simplest approach regards pixels as "samples" taken from centre



Reality (almost)



15,000 samples taken at pixel centres



Less noisy image
(see bowl rim,
broccoli and general
improvements)

240,000 samples with 4x4 averaging (gives 15,000)

Example

- Left – aliased image, right – anti-aliasing on GeForce3

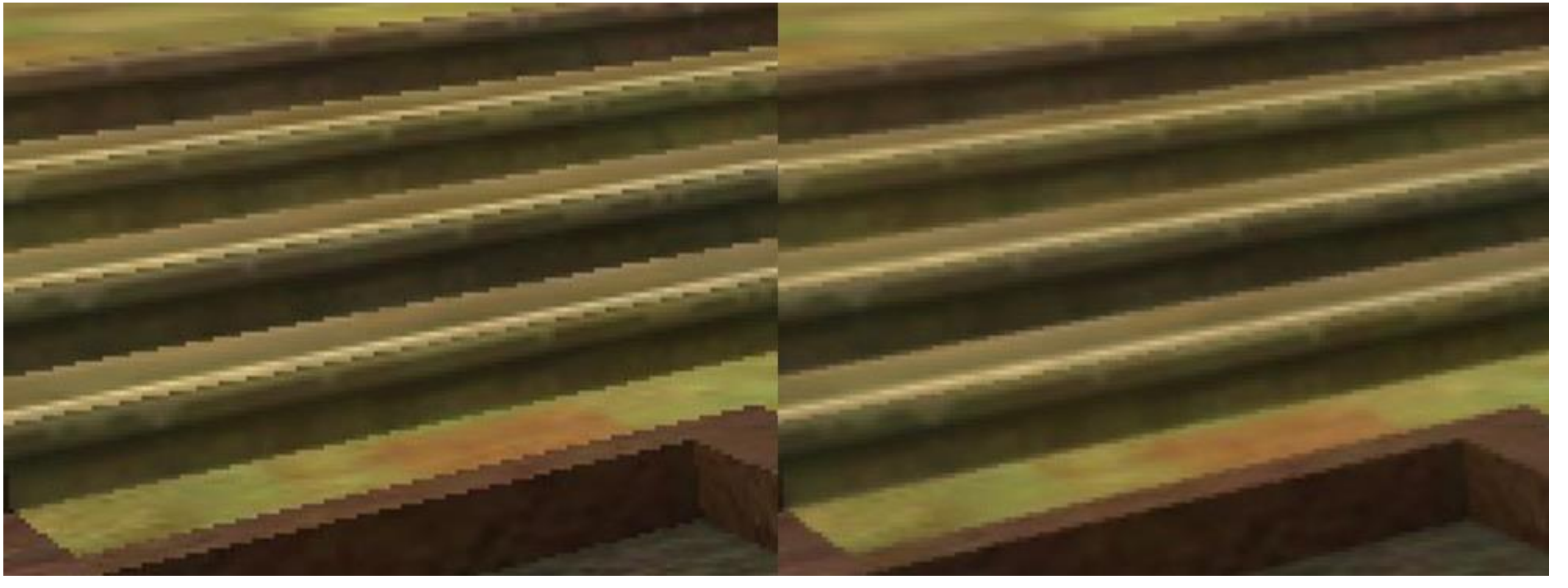
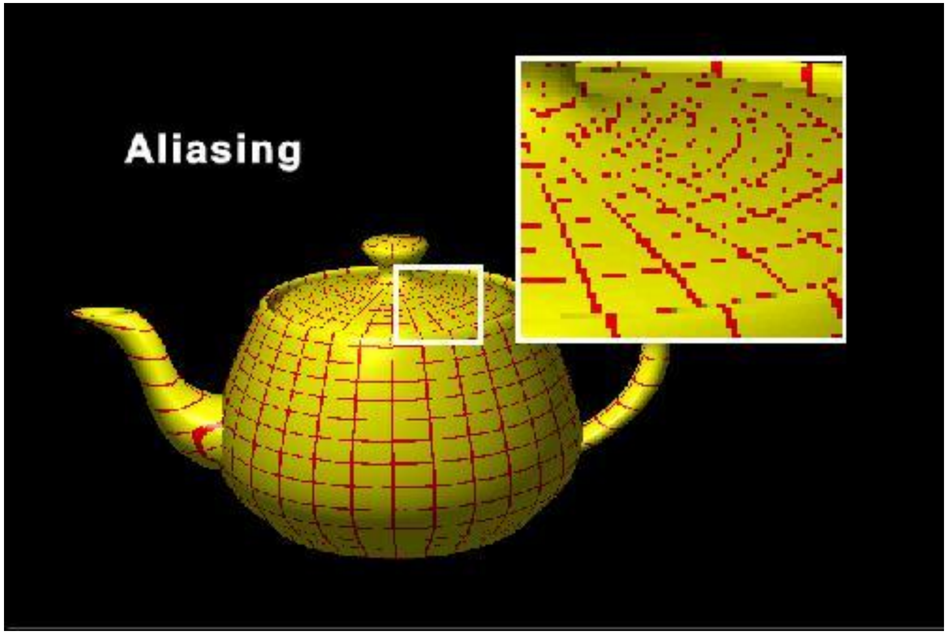
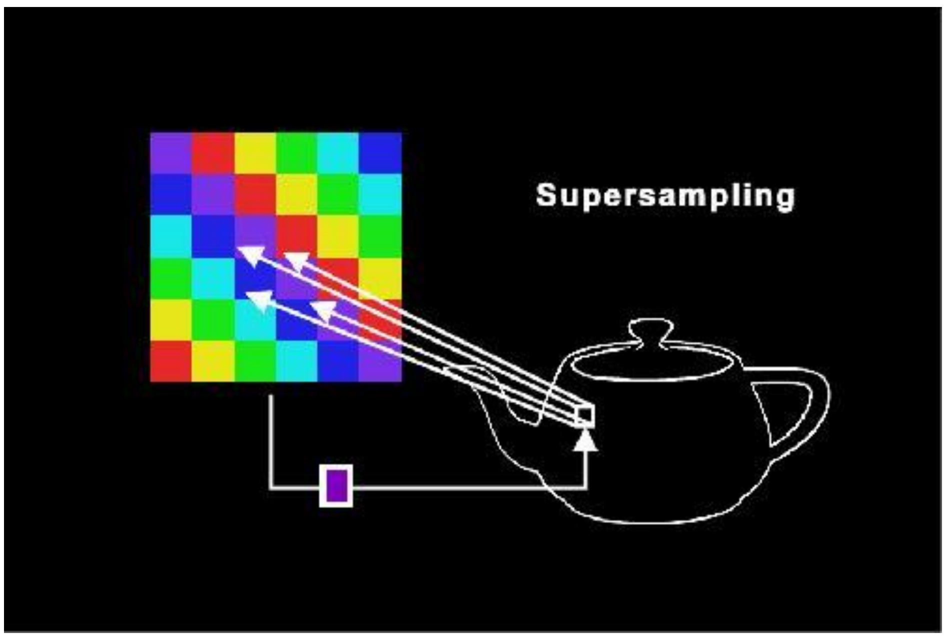
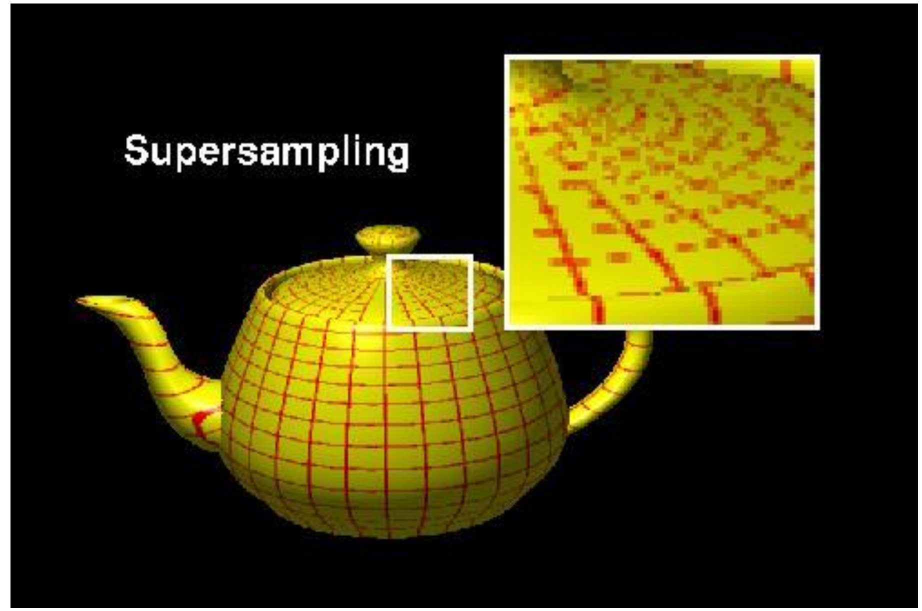


image from Toms Hardware

Example



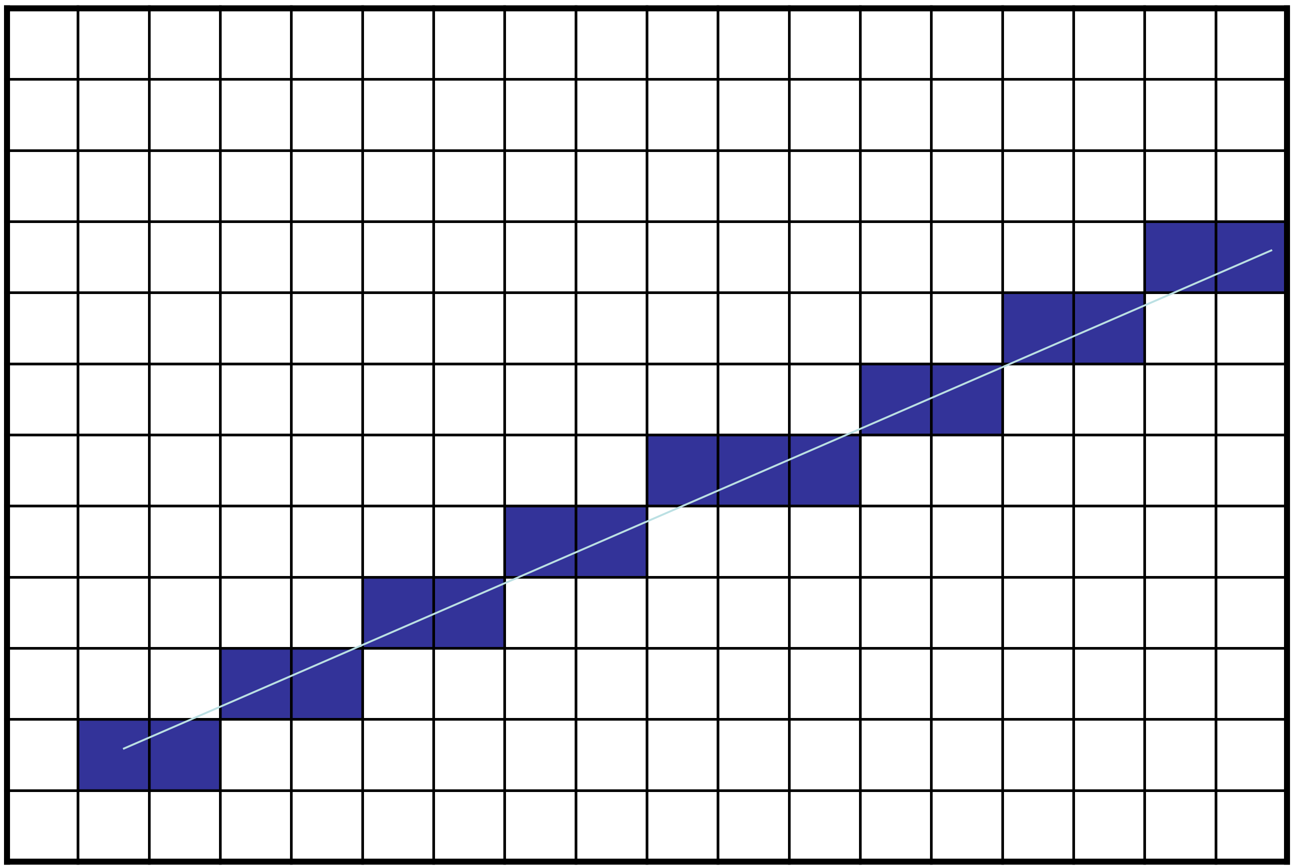




images from SIGGRAPH teaching materials

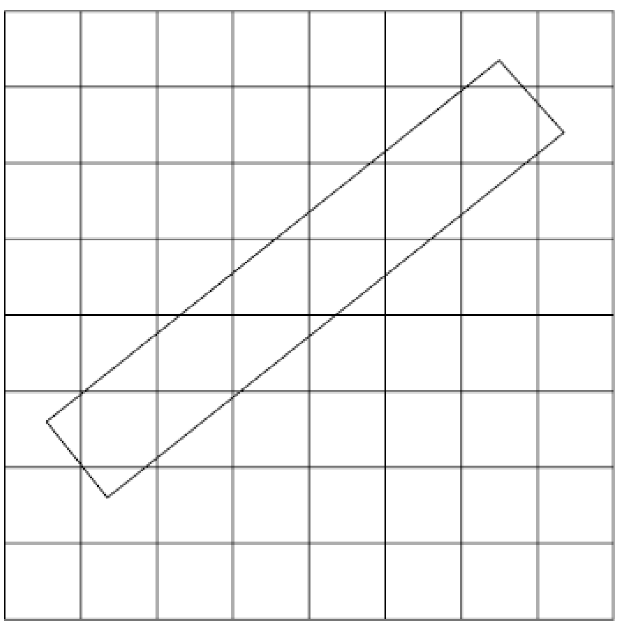
Aliased Line

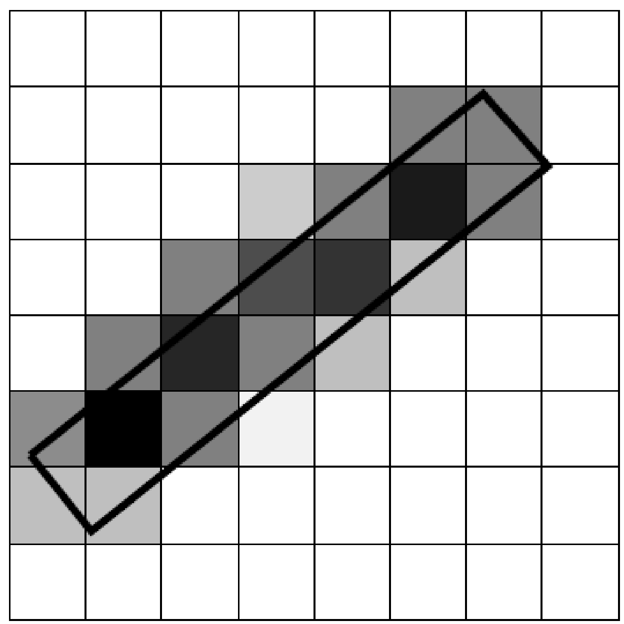
- high frequency+low sampling = jagged line



Solution

- Unweighted area sampling
- Treat line as a 1 pixel thick box
- Measure the area = x%, set colour appropriately



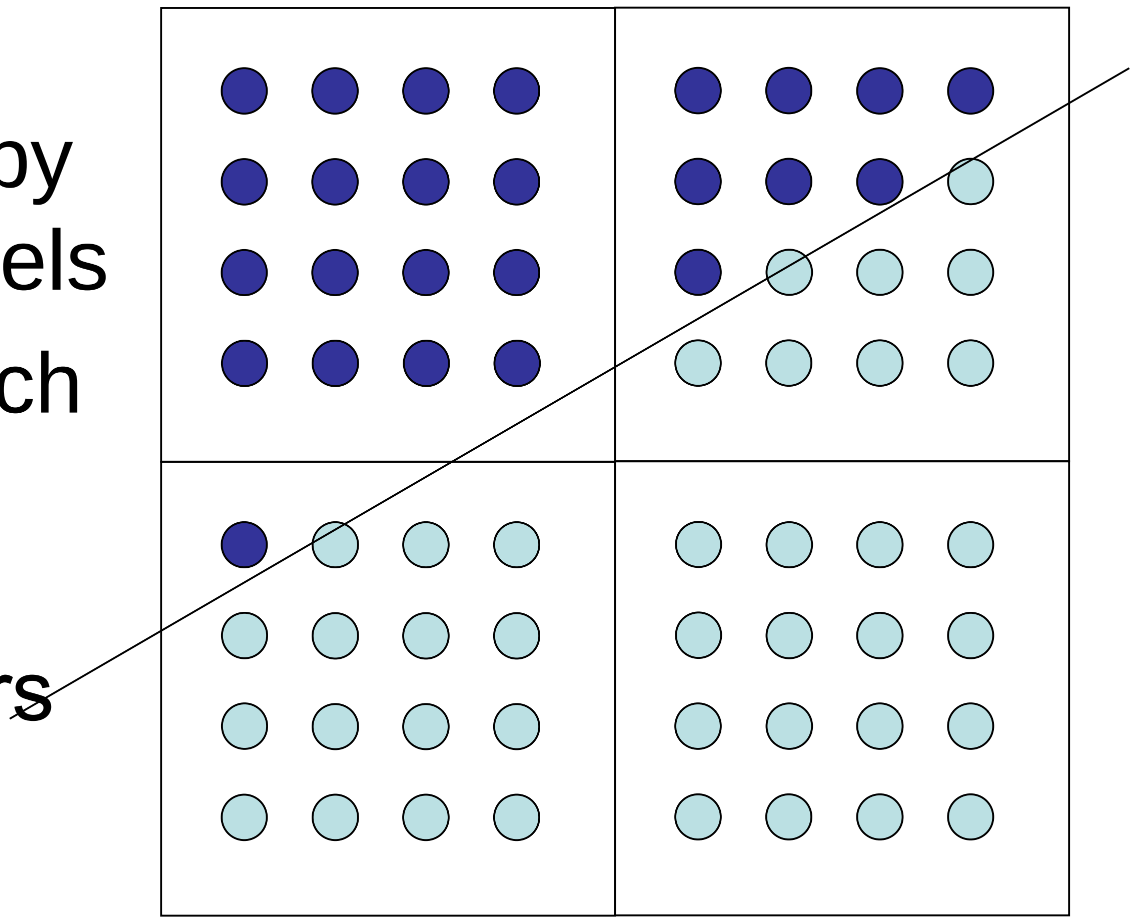


Details

- Now a smooth transition from on to off
- Calculated using area of pixel and line (accurate)
- Or subdivide the pixel into a number of subpixels – e.g. 16, and check if each one is within line or not
- Gives 16 levels from on to off (see next slide)

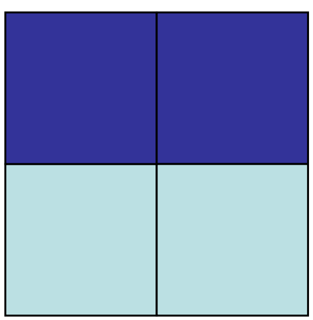
Super-sampling

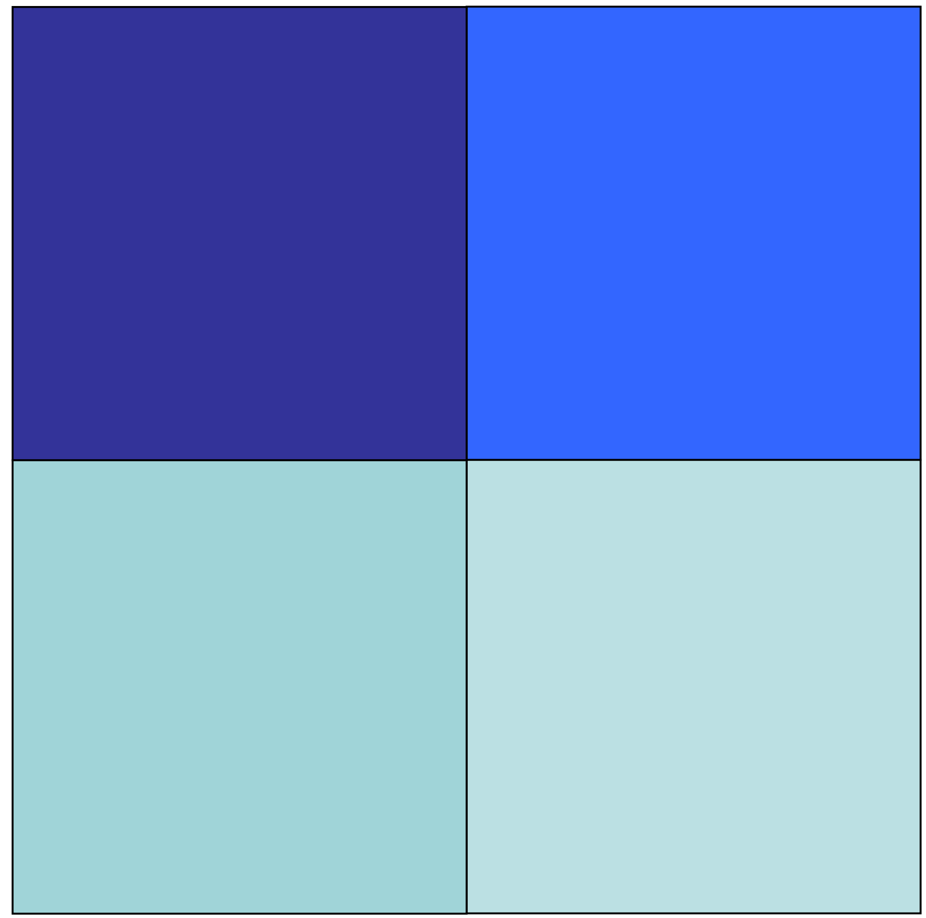
- 4 pixels
- Each sampled by 4x4=16 sub-pixels
- In next slide each pixel becomes average of 16 samples' colours



Super-sampling

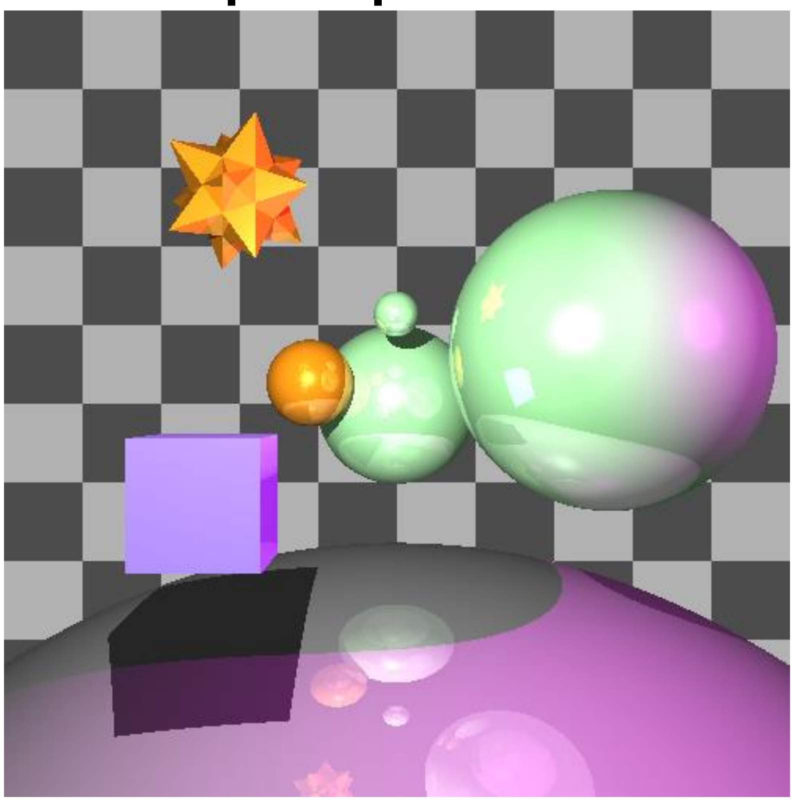
Without super-sampling
pixels would have been
set to these colours - check

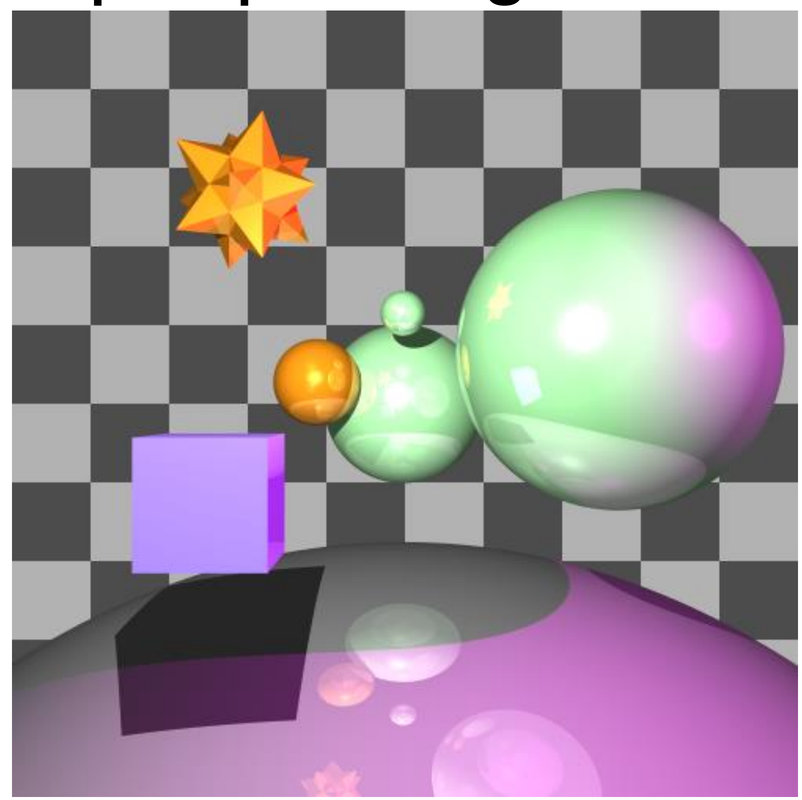




Super-sampling

- e.g. Ray-Tracing – trace more rays per pixel
  – 1 per pixel left, 36 rays per pixel right

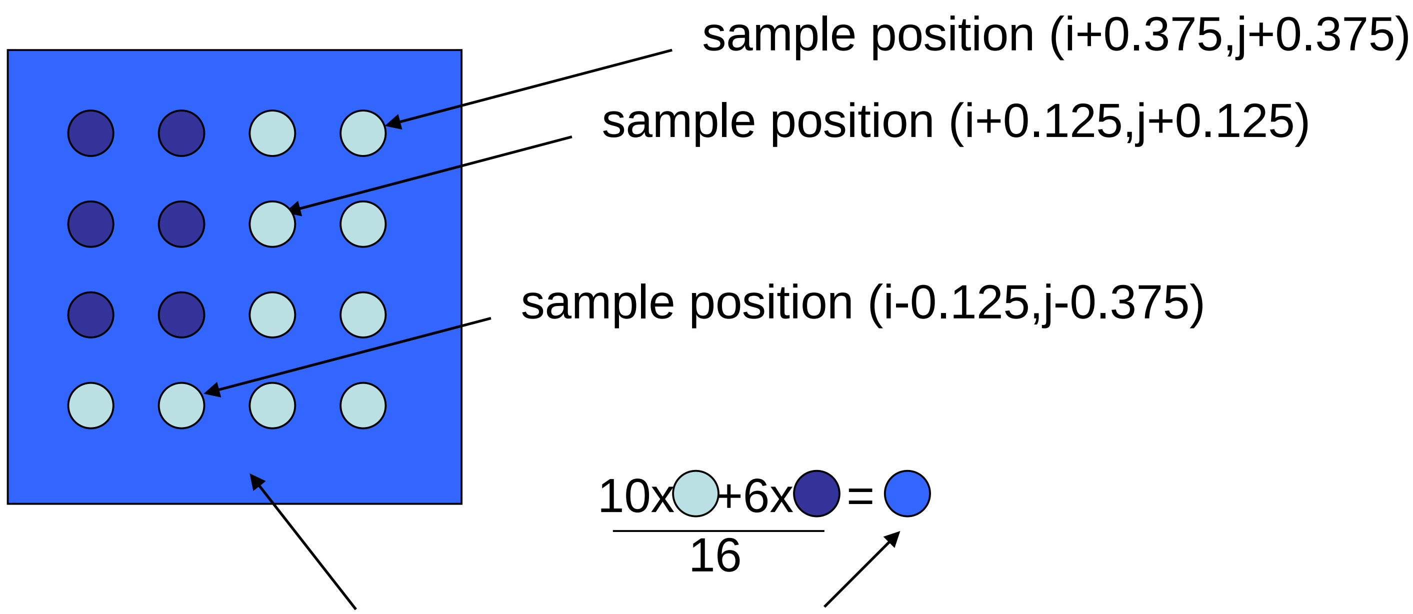




images from S. Depooter

Anti-Aliasing – **Super-sampling** =More samples per pixel

- Other sampling positions can be used



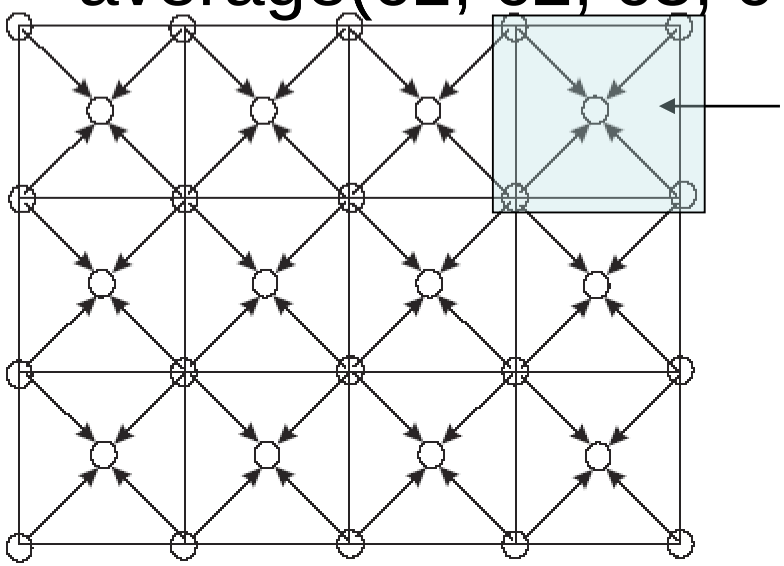
pixel (i,j) is set to the colour of the average of all 16 samples regularly spaced about its area

Super-Sampling

- More samples
  - give better images
  - take much longer to compute
  - e.g. 4x4 samples will take 16 times longer
- “Trade-off”
  - Computer Graphics is all about trading off visual accuracy for better speed

Adaptive Super-sampling

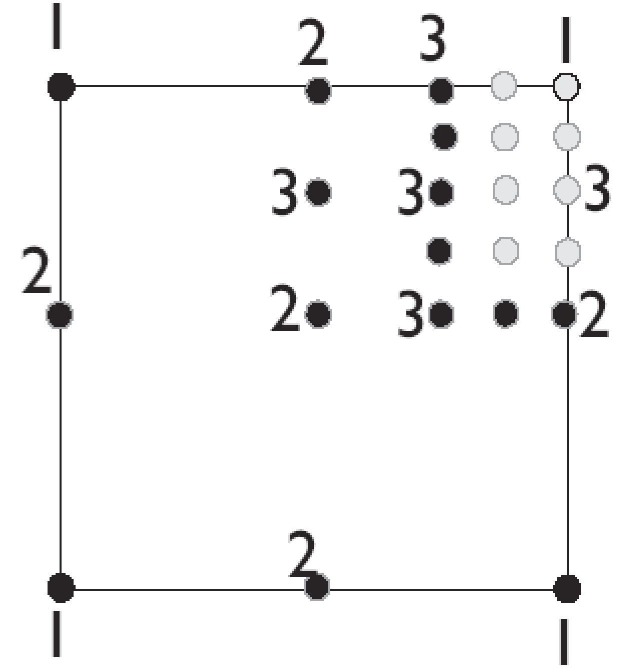
- Decide upon a threshold, t, e.g. t=20
- Sample the scene at each pixel corner
- Obtain 4 colours – c1, c2, c3, c4
- If (max(c1, c2, c3, c4)-min(c1, c2, c3, c4))≤t then pixel colour = average(c1, c2, c3, c4)



single pixel: colour is set to average of colours at 4 corners
Note: ixj pixels, (i+1)x(j+1) samples i.e. not much extra work

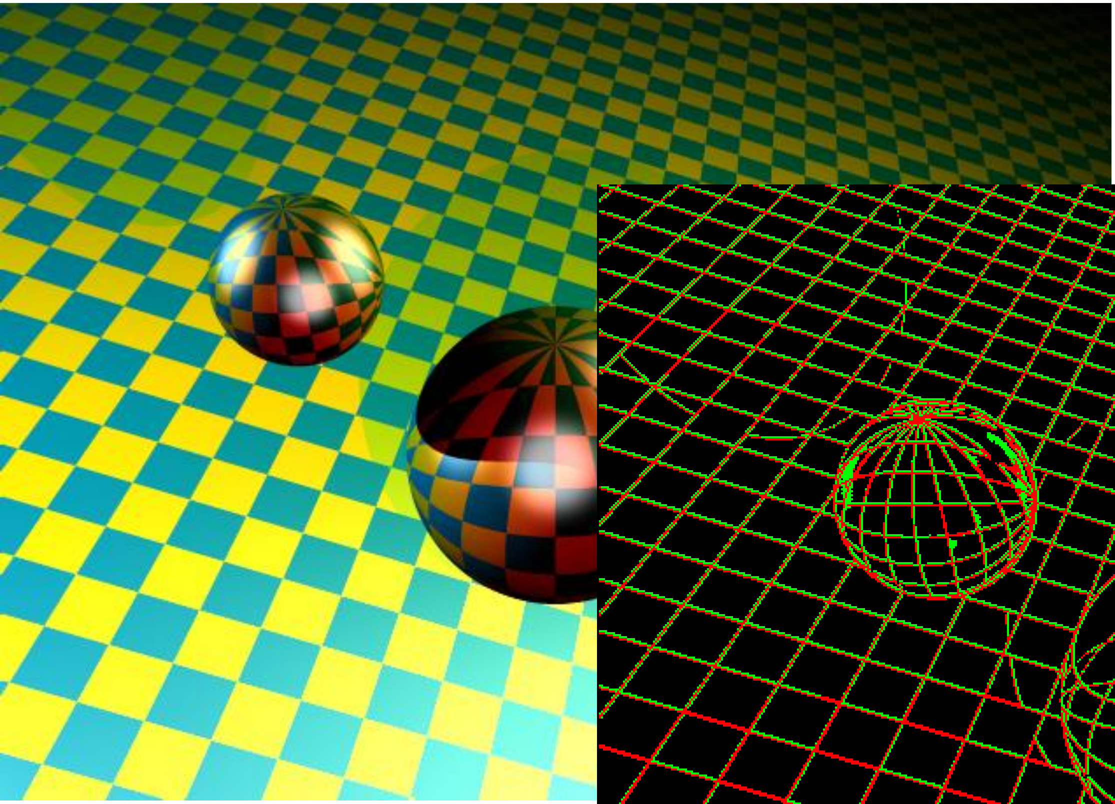
Adaptive Super-sampling

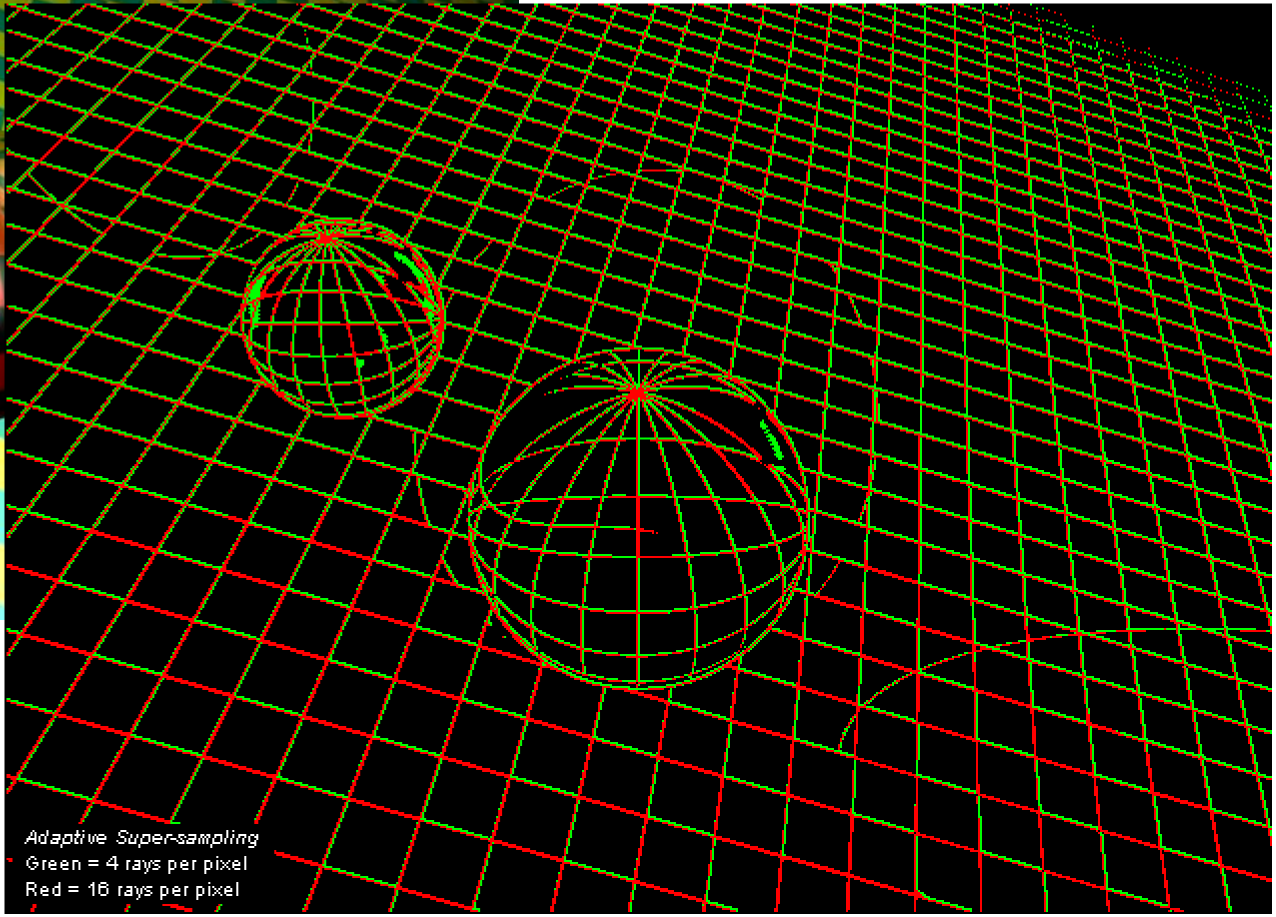
- Pixels labelled 1 were first 4 samples
- If max-min>t, then take additional samples
- These are labelled 2 in the picture
- We now recurse on the 4 new sub-pixels
- Recurse each one until max-min ≤ t, or until a limit is reached
- Final pixel is average of all samples



Example

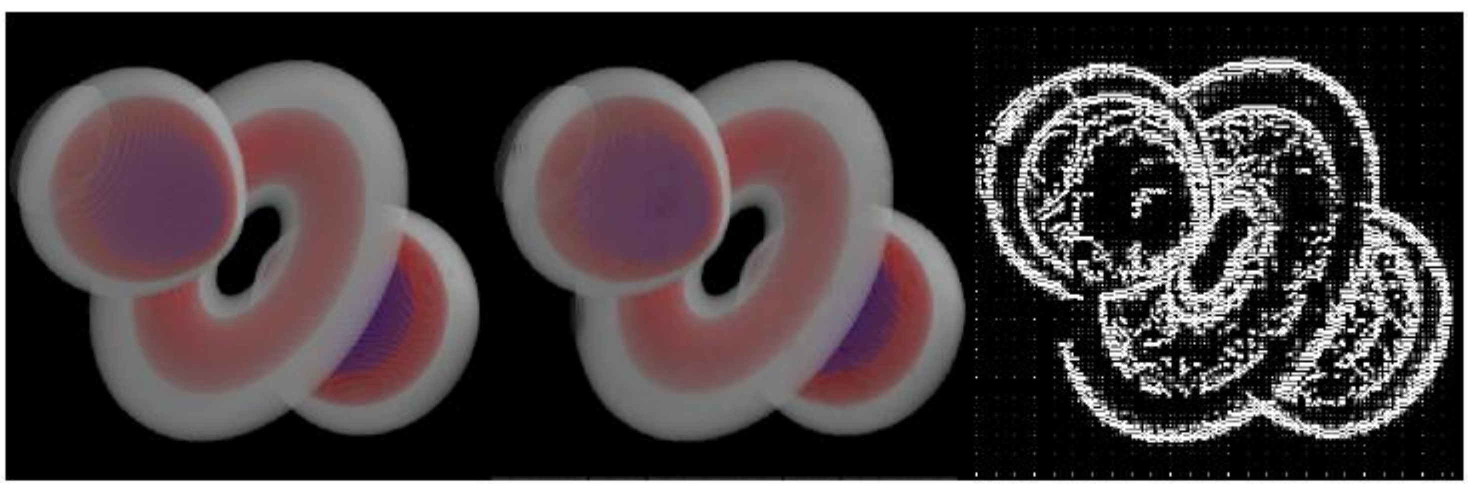
images from Ben Spencer
PhD student





Example

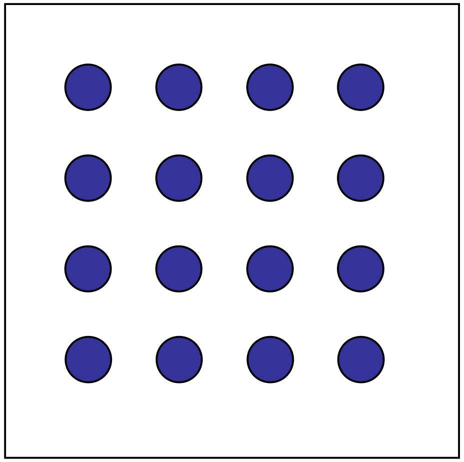
- 100x100 image = 10,000 samples
- 4x4 super-sampling = 160,000 samples
- 100x100 image, adaptively sampled = 34,335 samples in this case (samples shown on right)
- i.e. 3.4 times slower than 1 ray per pixel, but same visual quality as 4x4 supersampling (would take 16 times longer)



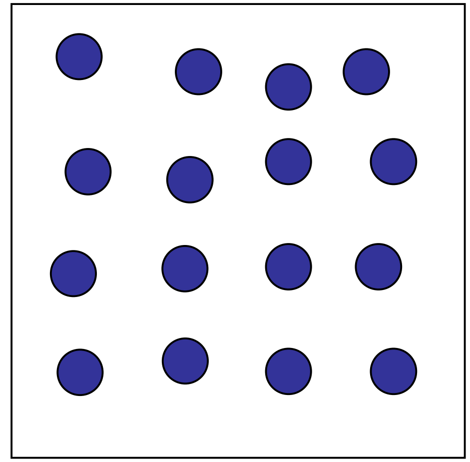
Summary

- Aliasing problems caused by under-sampling
- In images – high frequency/contrast regions
- Solved using
  - unweighted area sampling (good for drawing primitives (like lines, circles, etc.)
  - weighted area sampling (ditto), not studied
  - super-sampling (good for ray tracing)
  - adaptive super-sampling (ditto)
- Each has advantages and disadvantages - learn

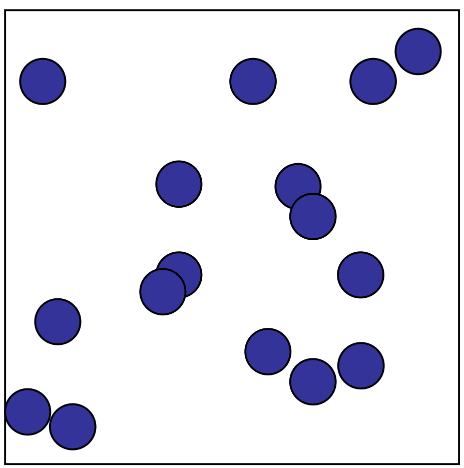
Sample Positions



Grid, easy to compute, can still lead to aliasing



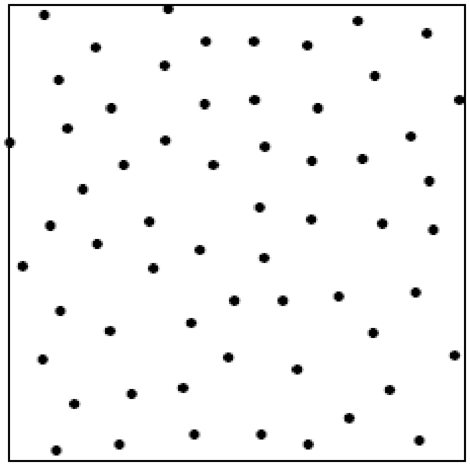
Jitter, using the grid, each sample is moved a random, but small amount, so that only one sample still occurs in each grid cell. The sample pattern is fast to compute, and does not suffer from too many problems



Random (or stochastic sampling), can lead to some areas being undersampled or oversampled

See next slide for 1 more

Sample Positions



Poisson-disk

Learn the name, advantages and disadvantages (and diagram), and image quality for each of the methods

Poisson disk. The initial sample is randomly placed. During an iterative process, further samples are randomly placed, but are immediately tested against all existing samples, and removed if they are closer than a certain distance to an existing sample.
This produces an excellent sampling pattern, but the placement algorithm is computationally intensive (higher complexity than the previous ones)