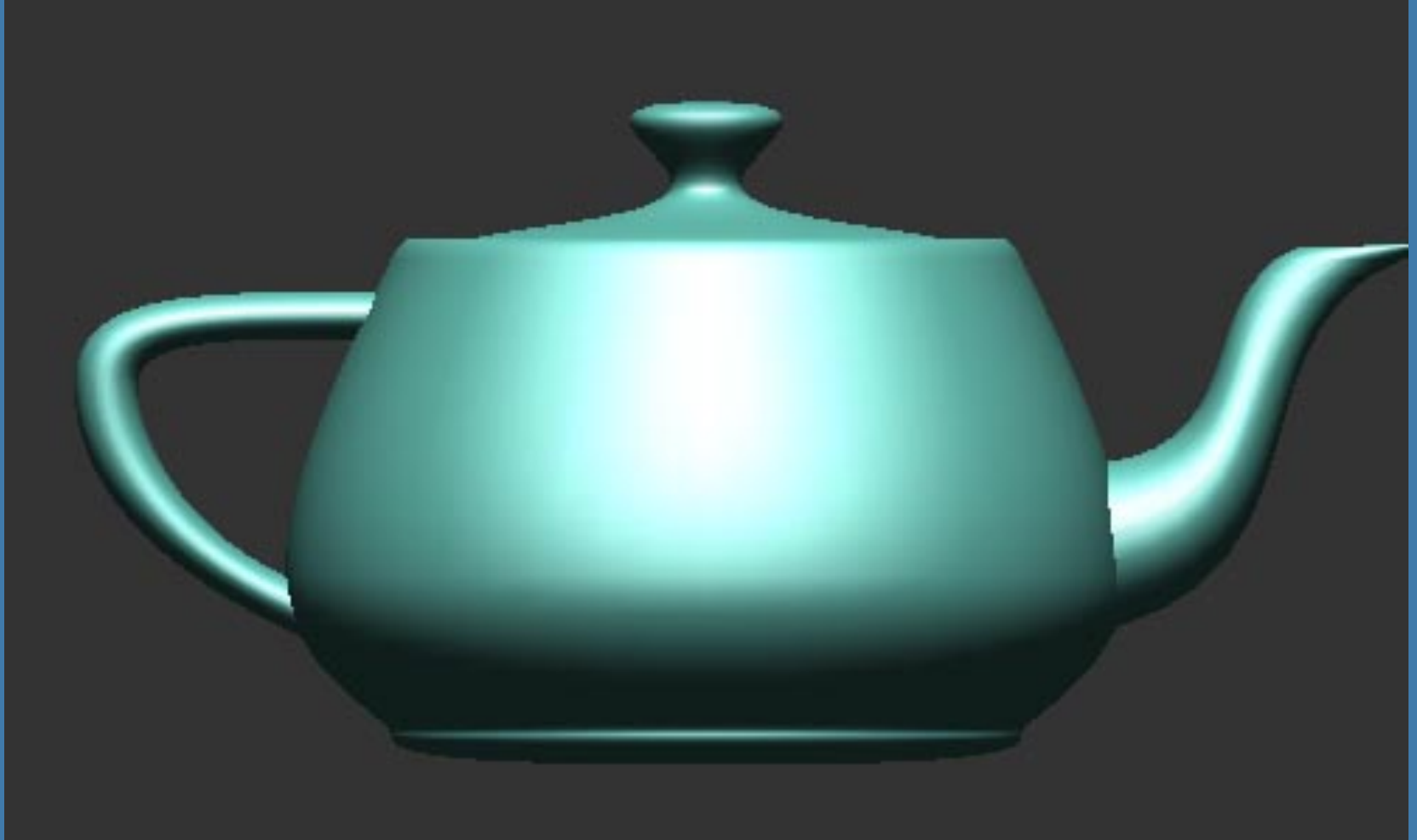# Filtering theory:
Battling Aliasing with Antialiasing

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Department of Computer Engineering

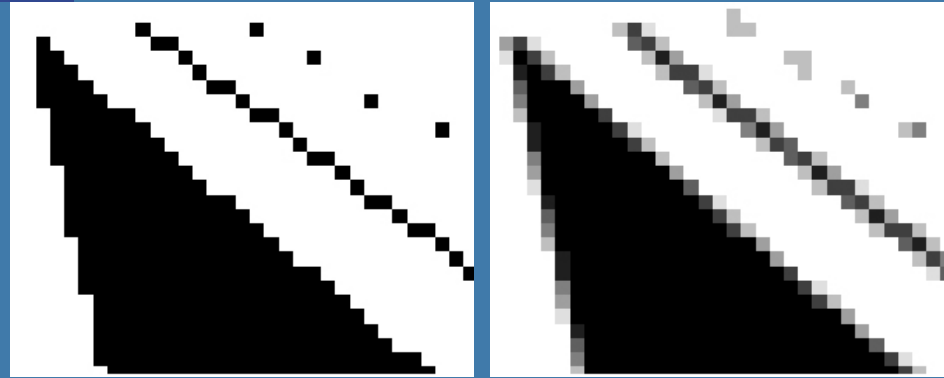Chalmers University of Technology

What is aliasing?

Why care at all?

- Quality!!

- Example: Final fantasy
  - The movie against the game
  - In a broad way, and for most of the scenes, the only difference is in the number of samples and the quality of filtering
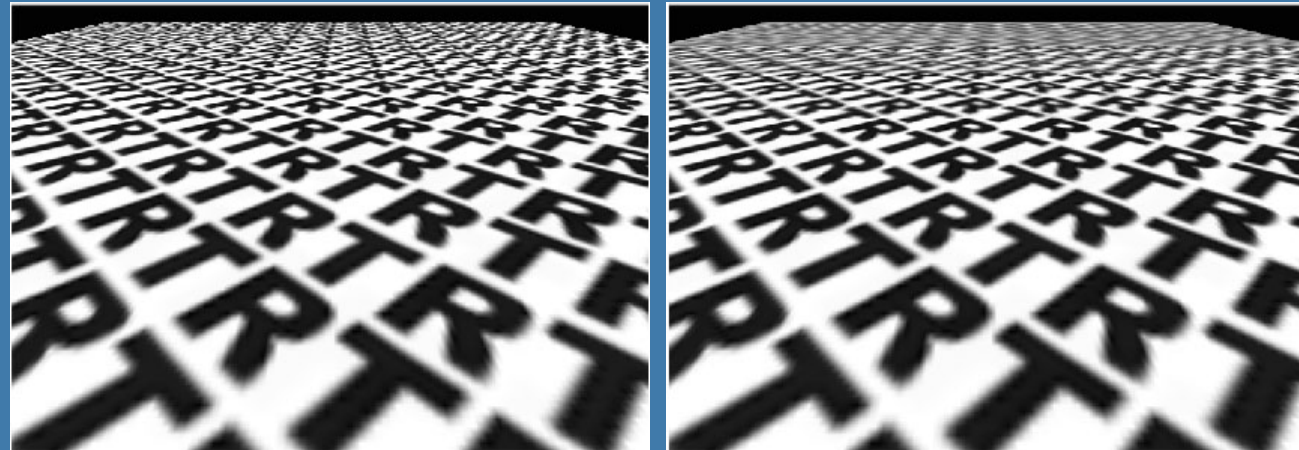
Computer graphics is a SAMPLING & FILTERING process!
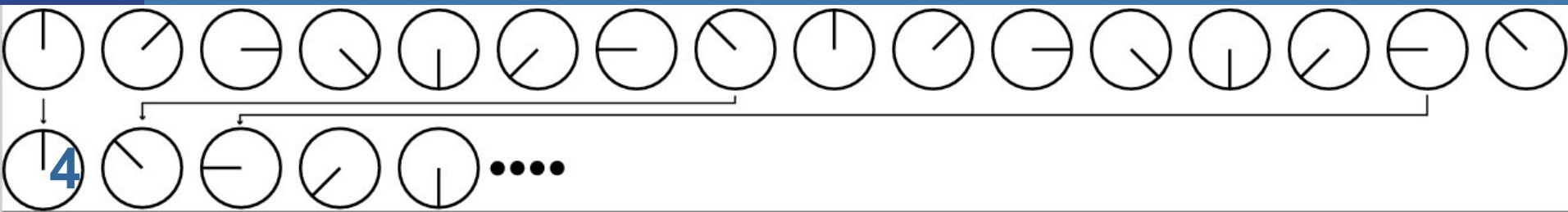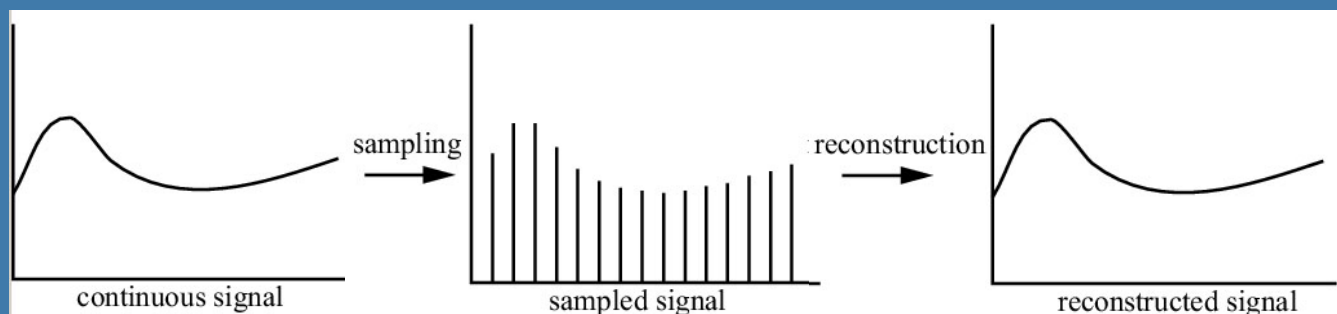
- Pixels
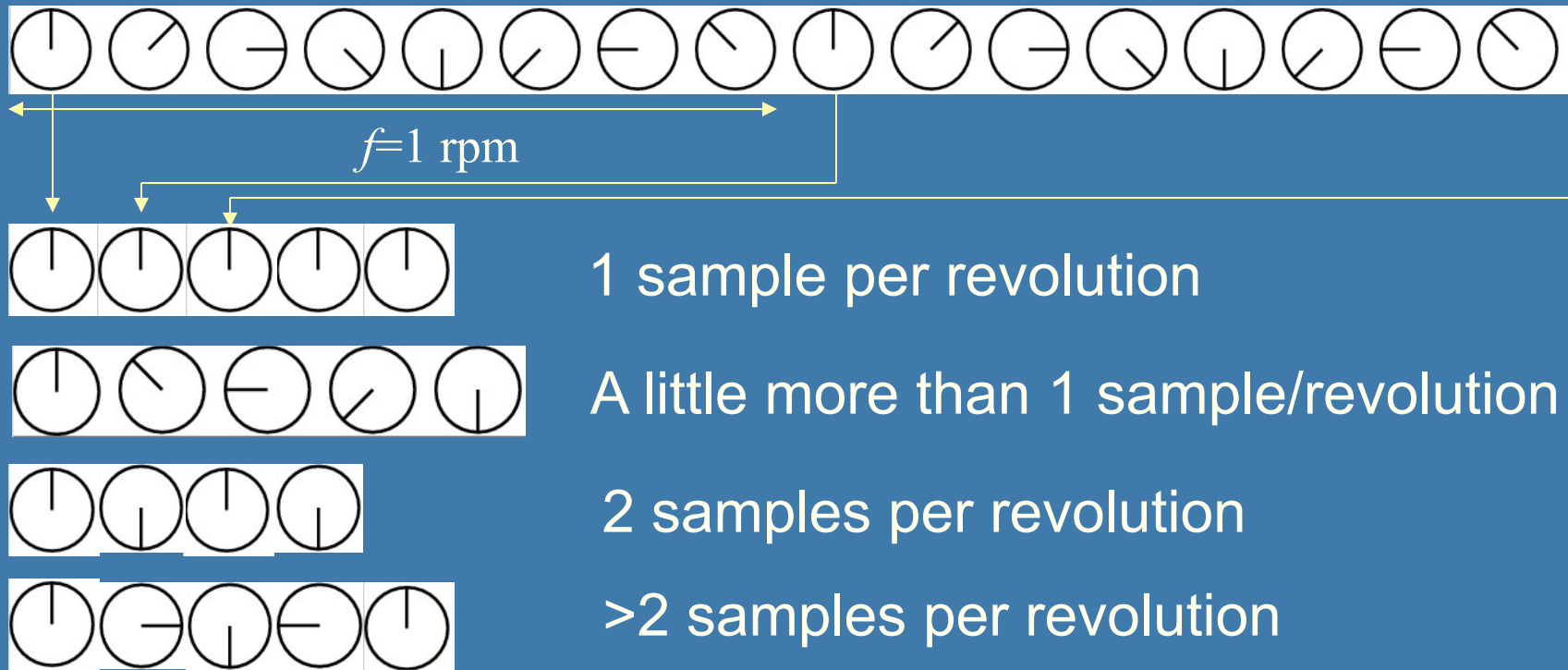

Demo

- Texture

- Time

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Sampling and reconstruction

- Sampling: from continuous signal to discrete
- Reconstruction recovers the original signal
- Care must be taken to avoid aliasing
- Nyquist theorem: *the sampling frequency should be at least 2 times the max frequency in the signal*
- Often impossible to know max frequency (bandlimited signal), or the max frequency is often infinite…

Sampling theorem

● Nyquist theorem: *the sampling frequency should be at least 2 times the max frequency in the signal*

f=1 rpm

1 sample per revolution

A little more than 1 sample/revolution

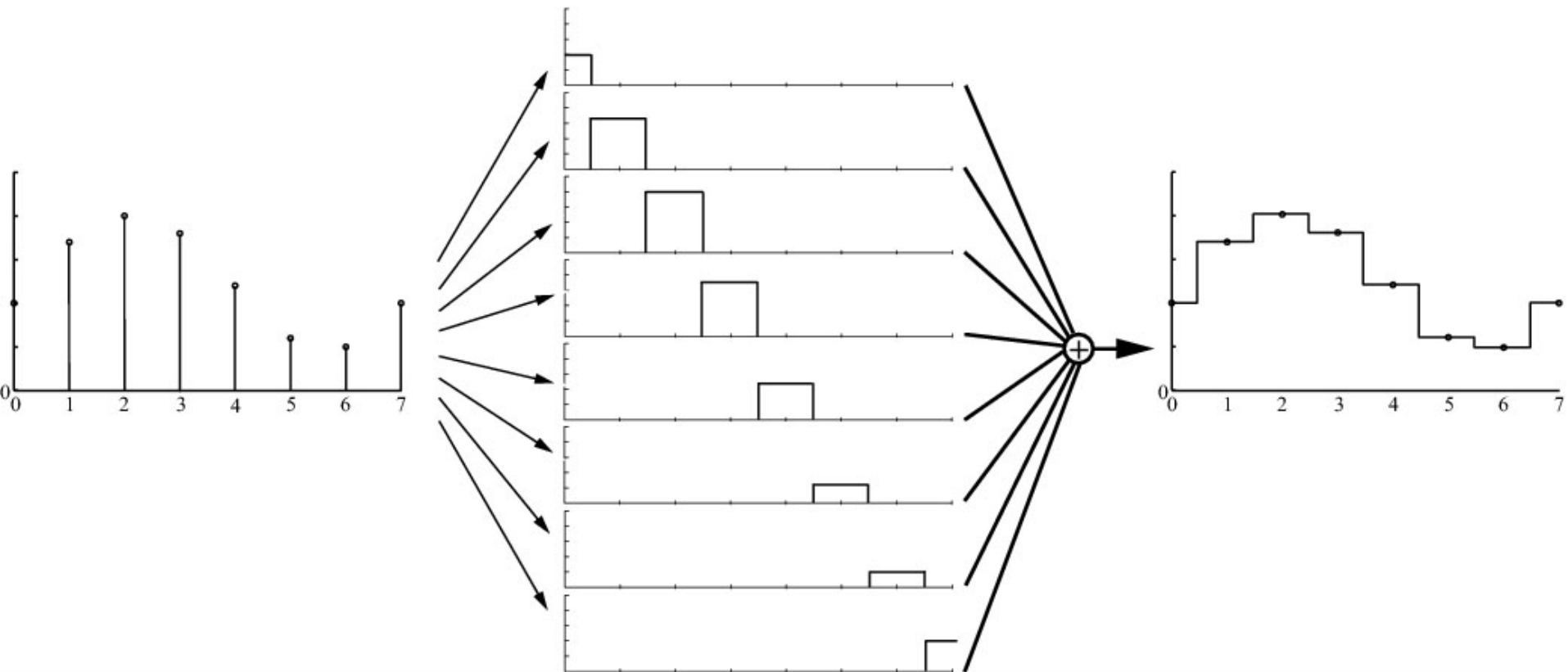2 samples per revolution

>2 samples per revolution

Sampling is simple, now turn to: Reconstruction

- Assume we have a bandlimited signal (e.g., a texture)
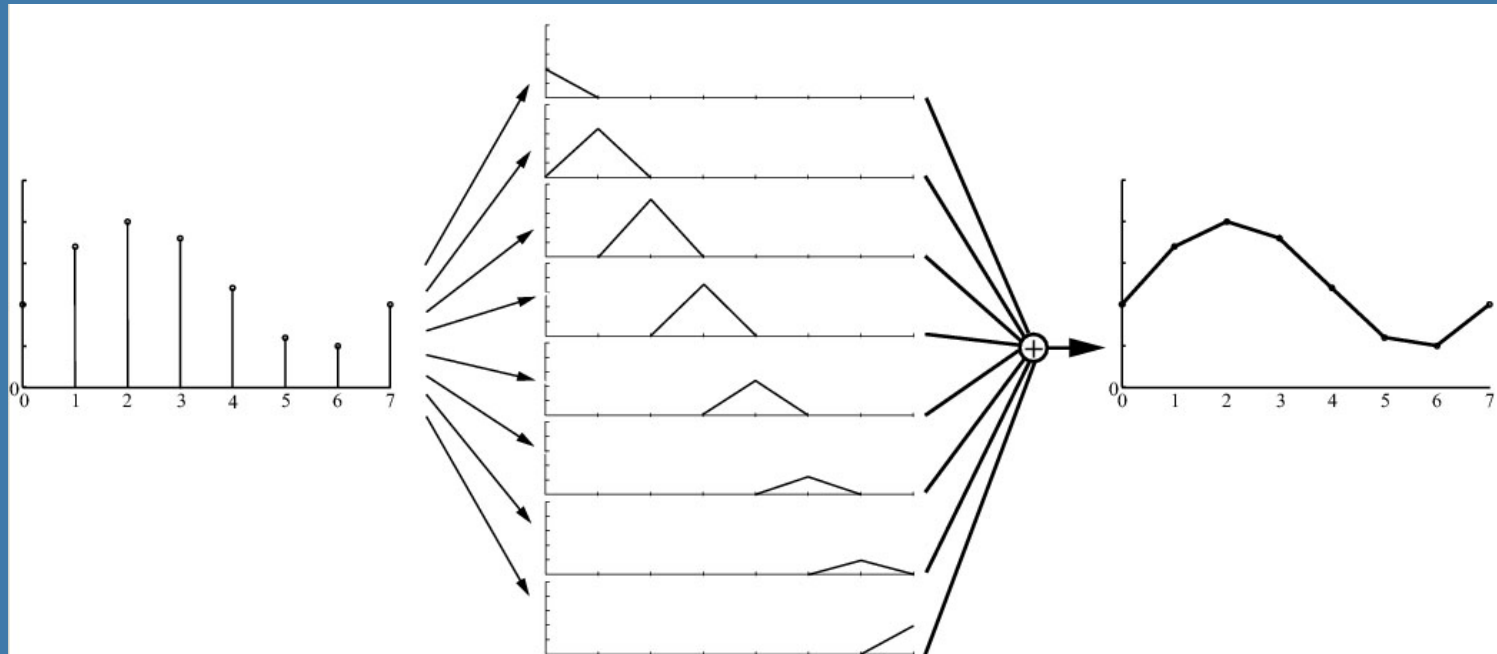- Use filters for reconstruction
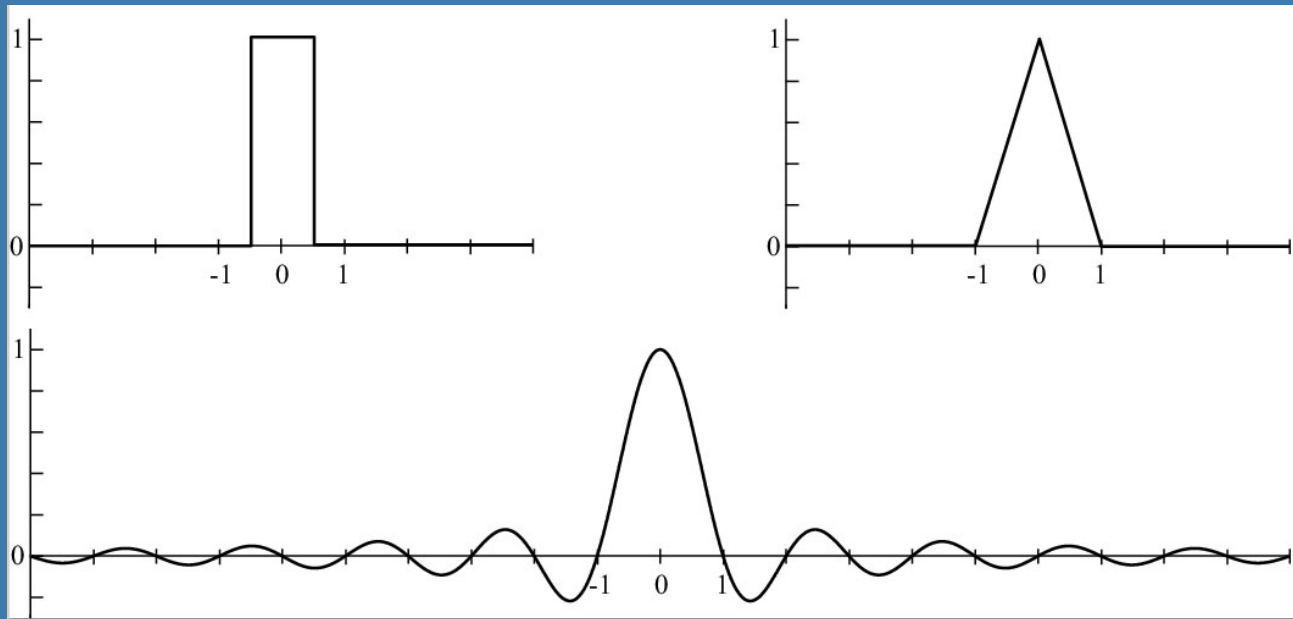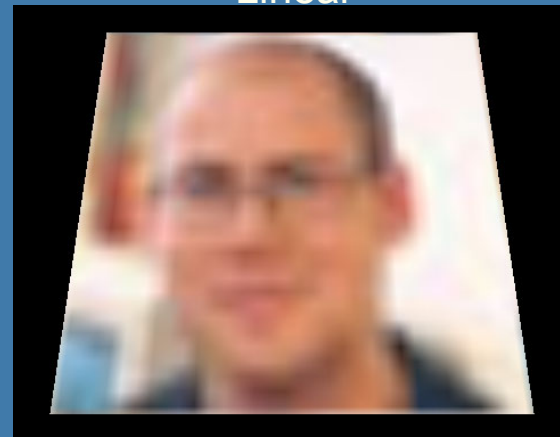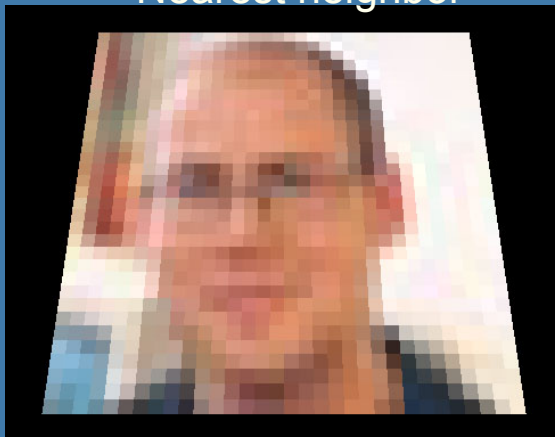
Reconstruction with tent filter

Nearest neighbor

Linear

32x32
texture

9

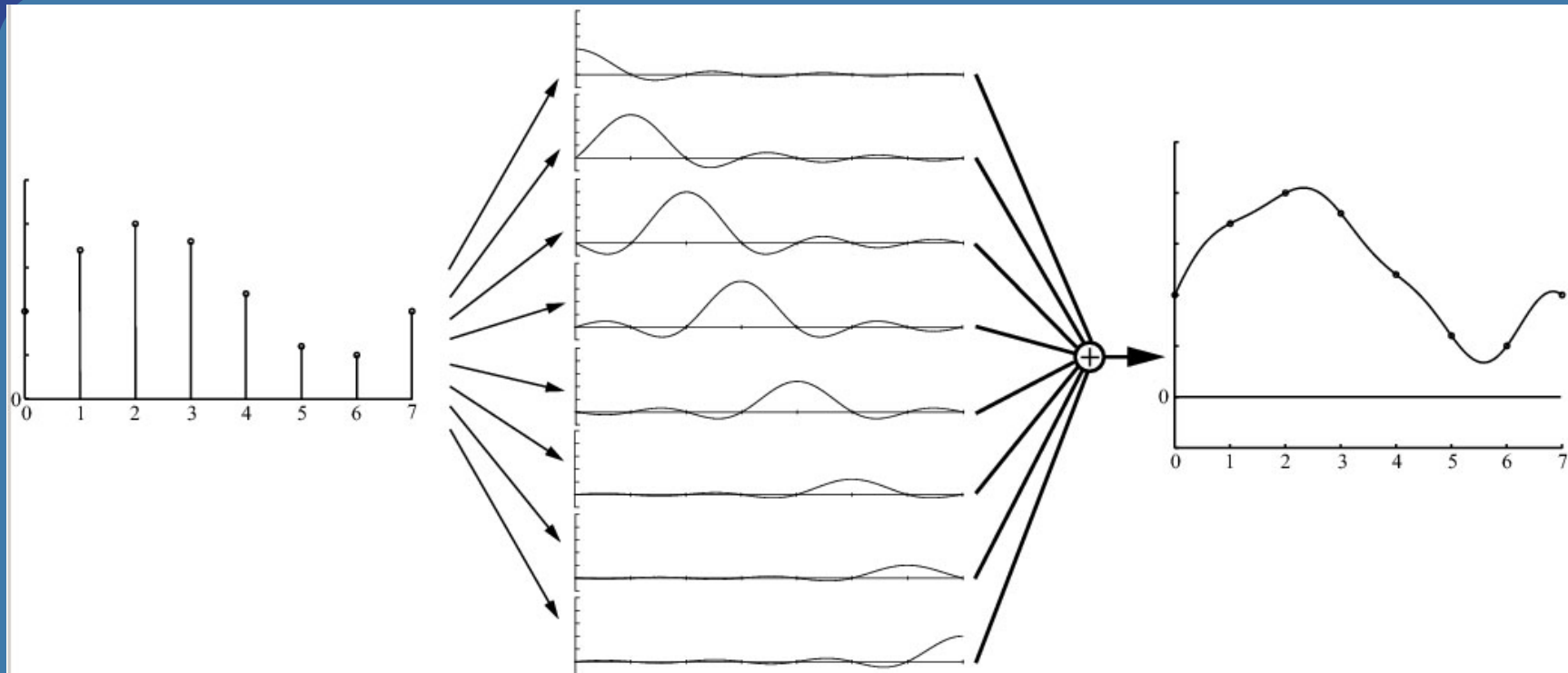ne-Möller © 2003

$$\text{sinc}\,(x) \equiv \begin{cases} 1 & \text{for } x = 0 \\ \dfrac{\sin x}{x} & \text{otherwise,} \end{cases}$$
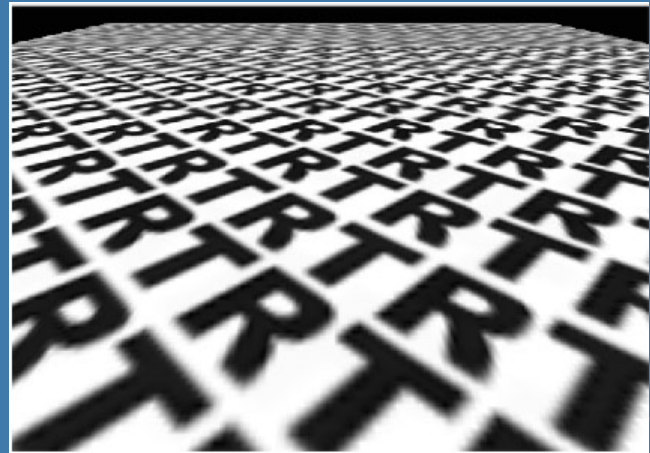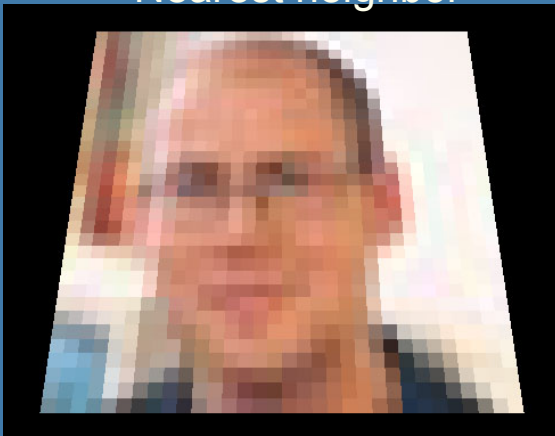
Reconstruction with sinc filter

- In theory, the ideal filter
- Not practical (infinite extension, negative)
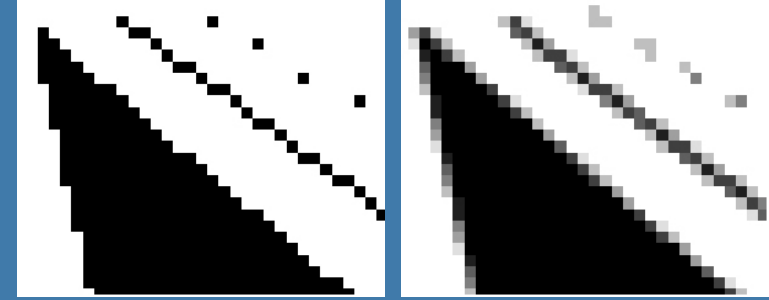
Resampling

Enlarging or diminishing signals

- Enlarging easy: just use filter (e.g. box or tent) to compute intermediate values.
- For minification, one way is to take the average of the corresponding samples
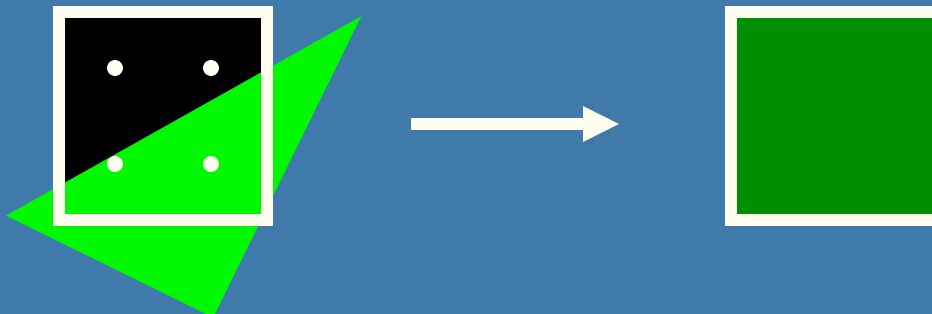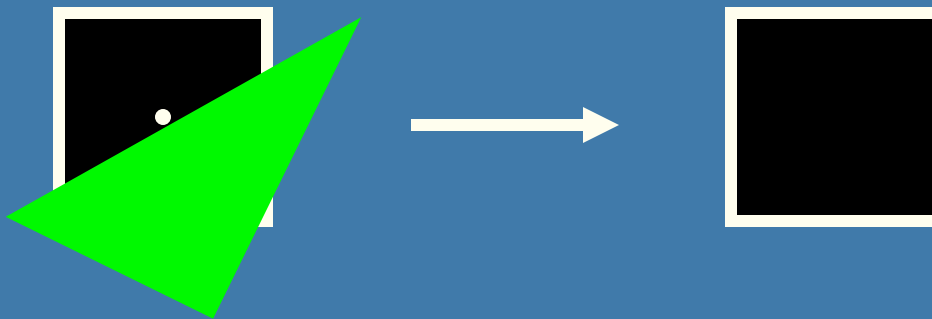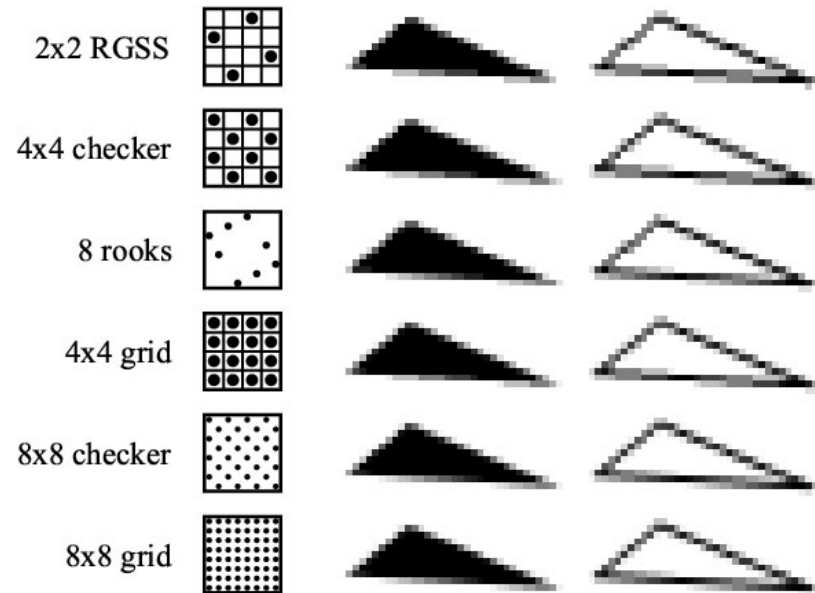
Nearest neighbor

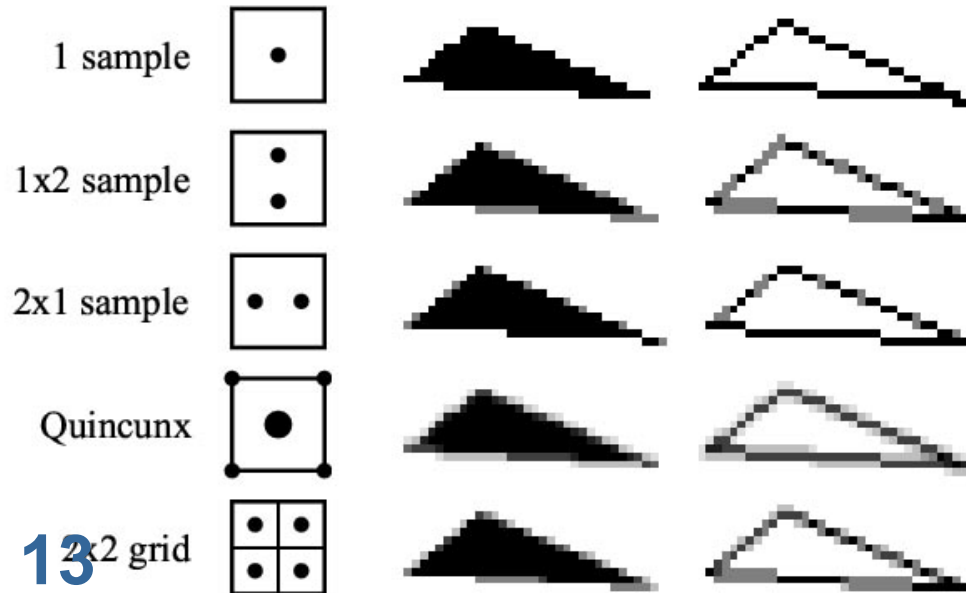32x32 texture

Screen-based Antialiasing

- Hard case: edge has infinite frequency
- Supersampling: use more than one sample per pixel

Formula and… examples of different schemes
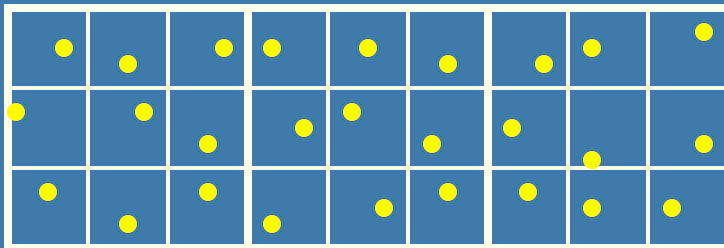
$$\mathbf{p}(x, y) = \sum_{i=1}^{n} w_i \mathbf{c}(i, x, y)$$

- w_i are the weights in [0,1]
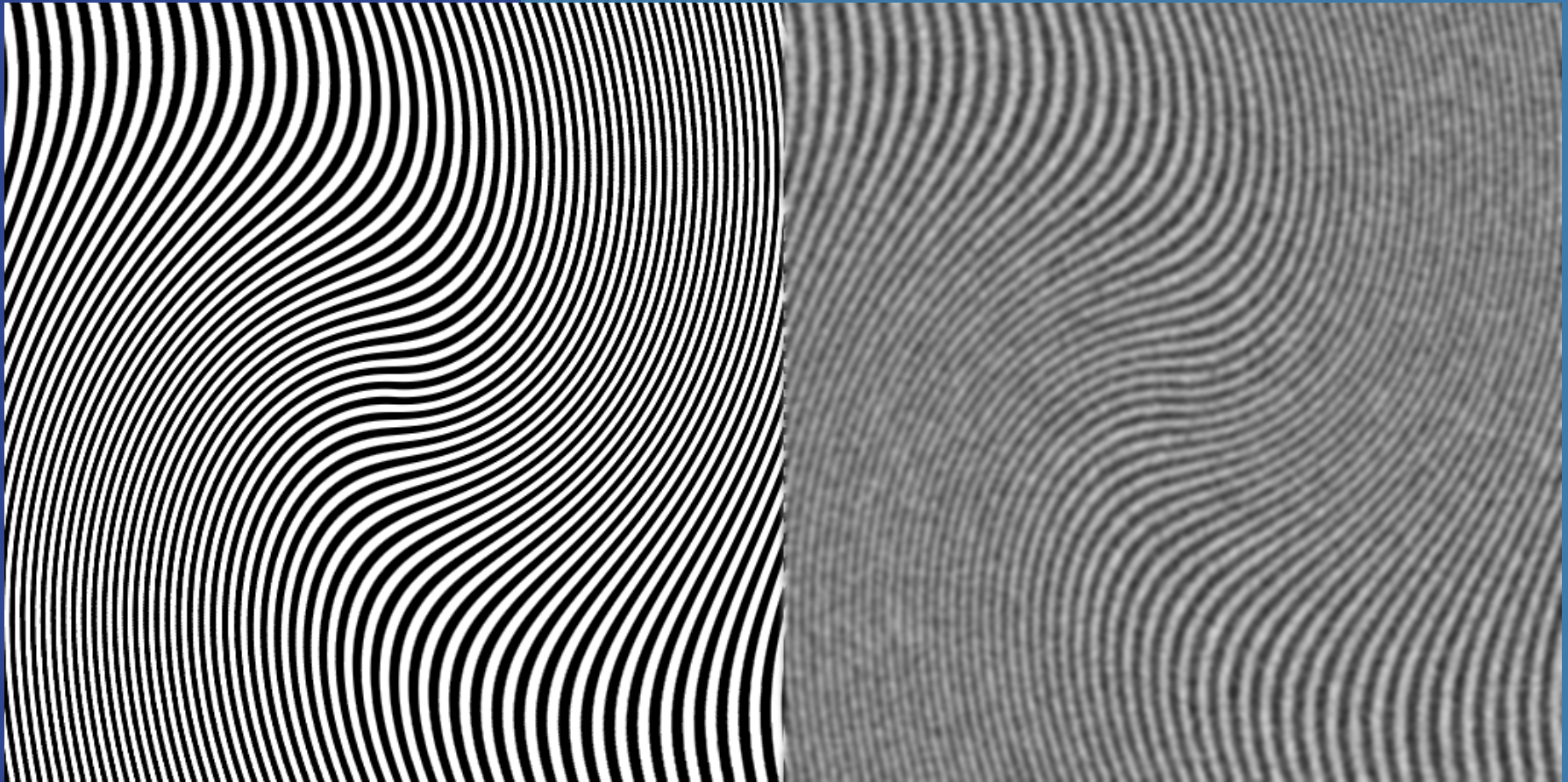- $\mathbf{c}(i,x,y)$ is the color of sample i inside pixel

Jittered sampling

- Regular sampling cannot eliminate aliasing – only reduce it!
- Why?
- Because edges represent infinite frequency
- Jittering replaces aliasing with noise
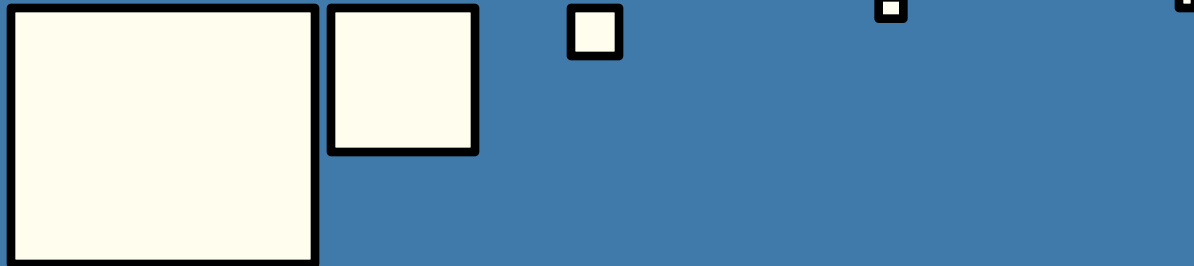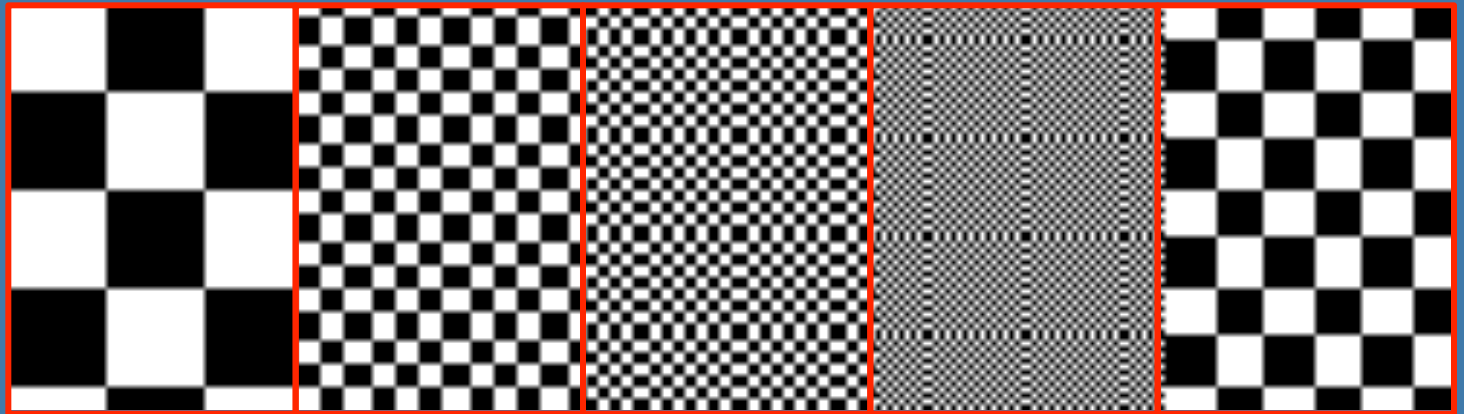- Example:

Moire example

Moire patterns

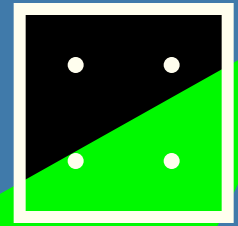Noise + gaussian blur

(no moire patterns)

Patterns

- Texture zoomed out until square < 1 pixel

SSAA, MSAA and CSAA

- Super Sampling Anti Aliasing
  - Stores duplicate information (color, depth, stencil) for each sample and fragment shader is run for each sample.
  - Corresponds to rendering to an oversized buffer and downfiltering.
- Multi Sampling Anti Aliasing
  - Shares some information between samples. E.g:
    - Frament shader only run once per fragment.
    - Stores a color per sample and typically also a stencil and depth-value per sample
- Coverage Sampling Anti Aliasing
  - Once per fragment:
    - Depth-value and executing the fragment shader
  - A coverage mask per pixel:
  - Each sample holds a 2-bit index into a storage of up to four colors per pixel

16x CSAA

Sample Storage

Color Storage
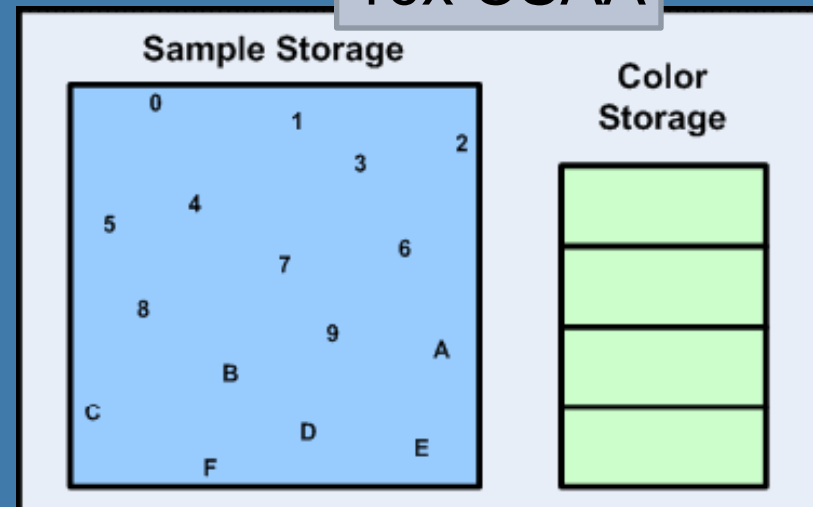
The A-buffer
Multisampling technique

- Takes >1 samples per pixel, and shares compuations between samples inside a pixel

- Supersampling does not share computations (depth, fragment shading)

- Examples:
  - Lighting may be computed once per pixel
  - Texturing may be computed once per pixel

- Strength: aliasing edges (and properly handling transparency)

The A-buffer

- To deal better with edges: use a coverage mask per pixel
- Coverage mask, depth, & color make up a fragment
- During rendering fragments are discarded when possible (depth test)
- When all polygons have been rendered, the fragments are merged into a visible color
  - Allows for sorting transparent surfaces as well
 - But costs memory
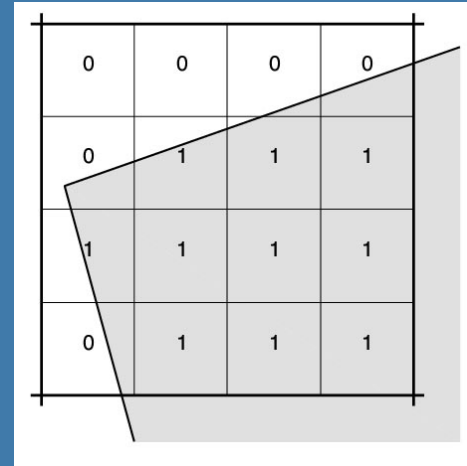
Another multisampling techniqe Quincunx
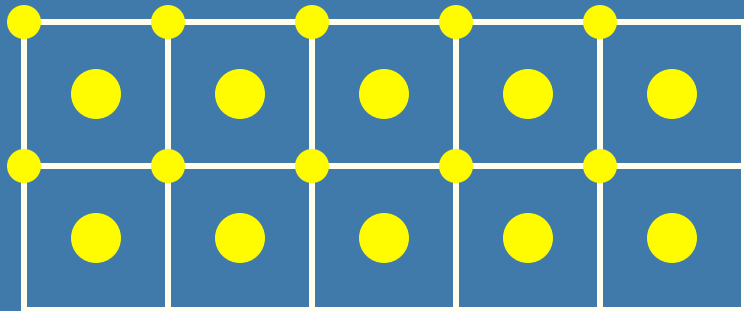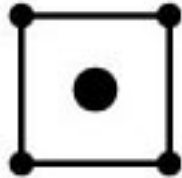
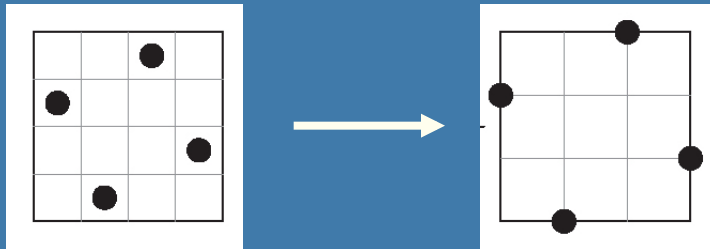- Generate 2 samples per pixel at the same time
- w_1=0.5, w_2=0.125, w_3=0.125, w_4=0.125, w_5=0.125 (2D tent filter)
- All samples gives the same effect on the image (mid pixel = 0.5, corner pixels = 4*0.125=0.5)
- Was available on NVIDIA GeForce3 and up
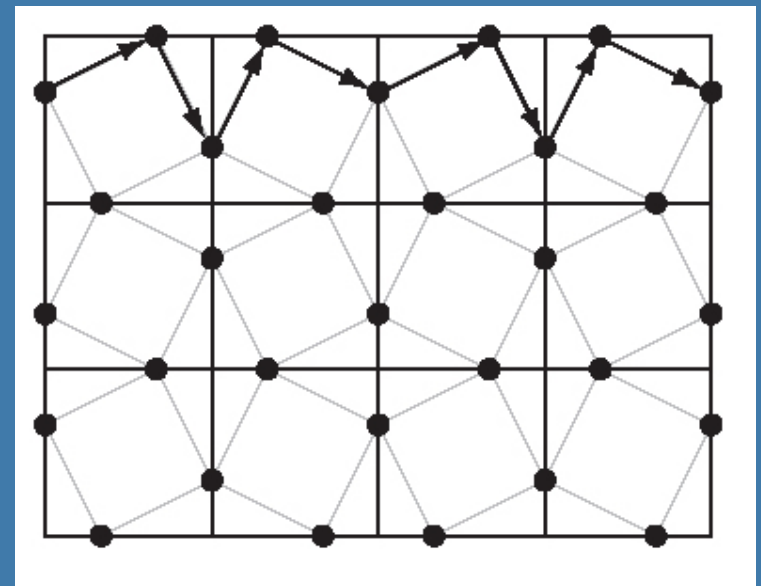
Yet another scheme: FLIPQUAD multisampling

- Recap, RGSS:
  - One sample per row and column
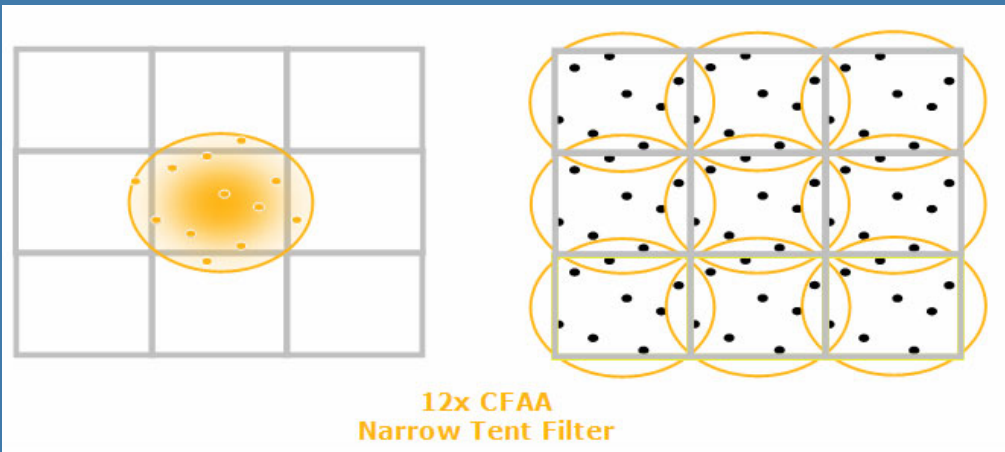
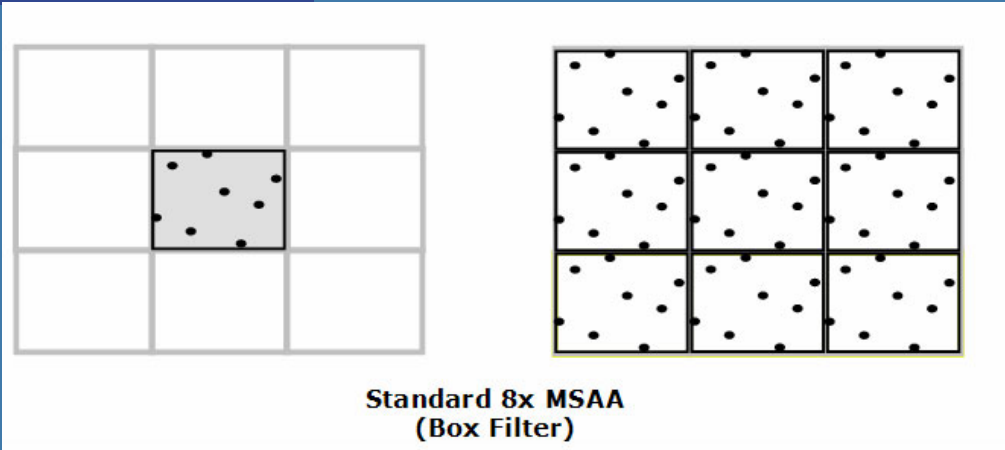- Combine good stuff from RGSS and Quincunx
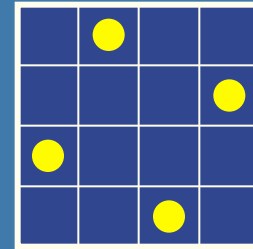
Demo

- Weights: 0.25 per sample
- Performs better than Quincunx

ATI Radeon 2900

Standard 8x MSAA
(Box Filter)

12x CFAA
Narrow Tent Filter

From www.pcper.com

● Examples of 2 filter modes

More on filtering theory and practice

- Especially important for texturing and filtering of textures
- More about this in next lecture

THE END

Hand in your
Muddy Cards