

# CS 112 - Sampling and Aliasing



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Slide 1



## Analog vs Digital

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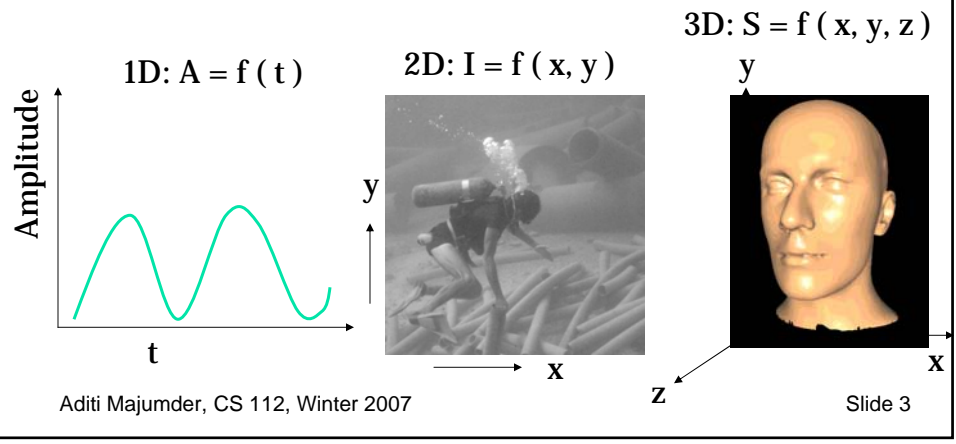
- God has created the world analog
- Man has created digital world

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Slide 2

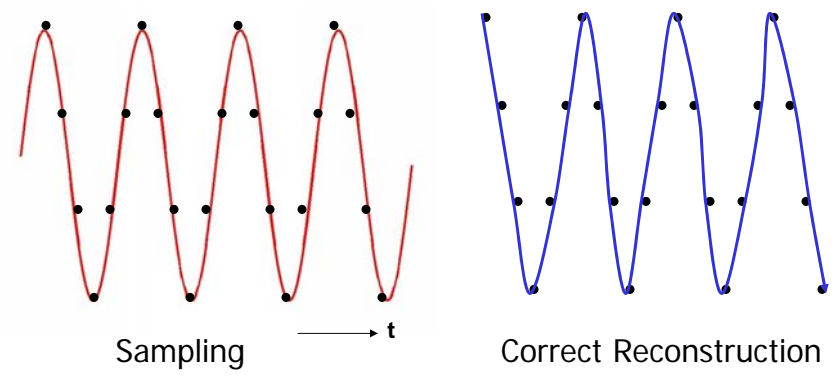
# Analog signals

- Function dependent on single or multiple variables
- Defined at **any** value of the dependent variable



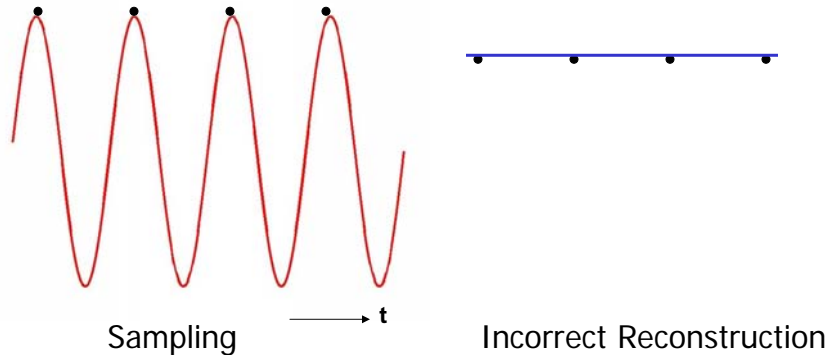
# Digital Signals

- Defined at only few values of t



## Digital Signals

- Whether you can reconstruct correctly depends on how you sample – sampling rate



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Slide 5

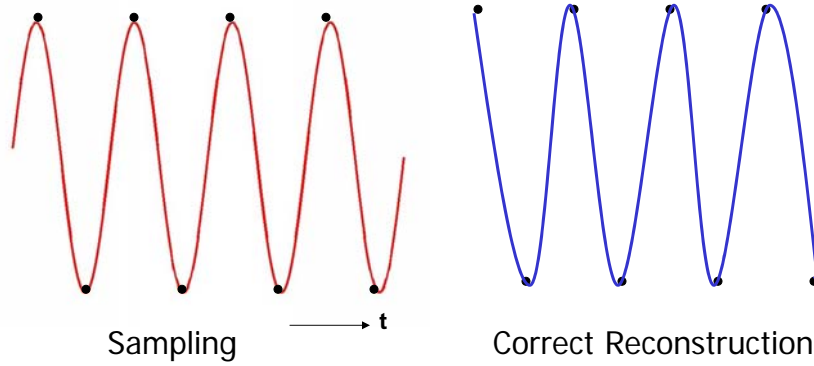
## Nyquist Rate

- Consider only sine waves
- If you sample **at least** at twice the frequency (2 samples per cycle), signal can be reconstructed correctly
  - More the sampling rate, better the reconstruction
- If less than twice the frequency, cannot reconstruct correct

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Slide 6

# Nyquist Rate Sampling

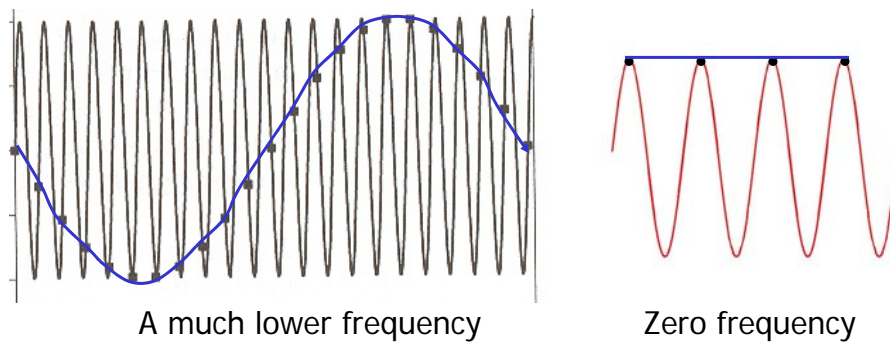


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Slide 7

# Aliasing

- Aliasing: Incorrect representation of some entity

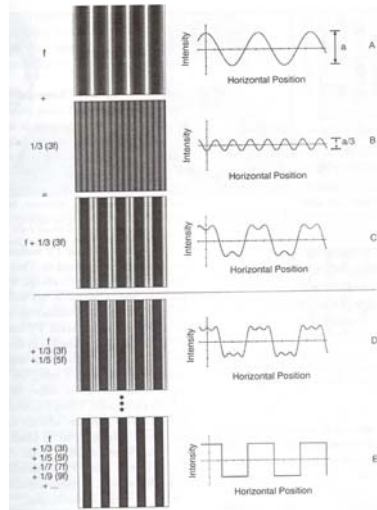


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Slide 8

# How does sinusoids help?

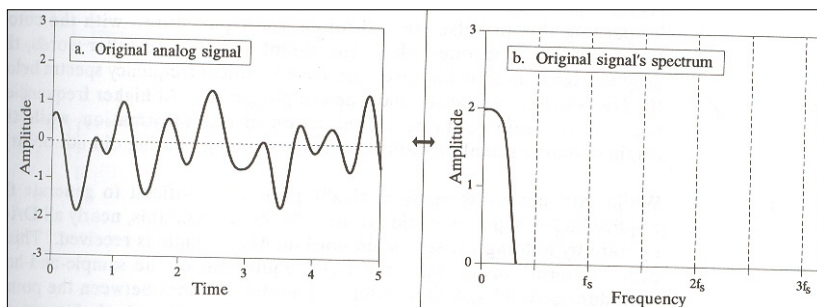
- Any signal can be expressed as a sum of sinusoids of different frequencies
  - Amplitude
  - Phase



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Slide 9

# Spectral Analysis



Time Domain

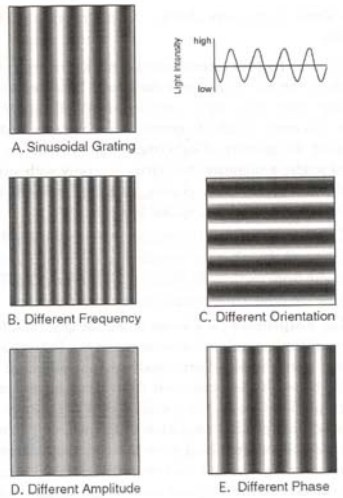
Frequency Domain

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Slide 10

# For 2D images

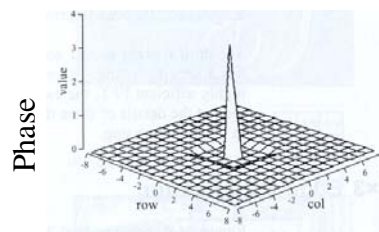
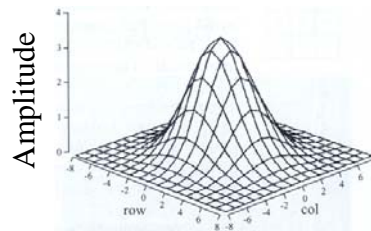
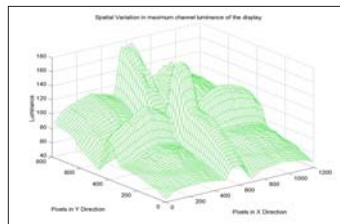
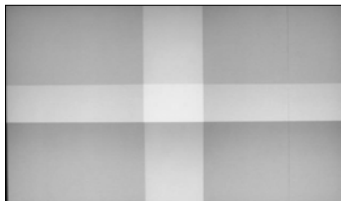
- Any signal can be expressed as a sum of sinusoids of different frequencies
  - Amplitude
  - Phase
  - Orientation



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Slide 11

# Extending it to 2D



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## Frequency Content

- Lower frequencies : Global Pattern
- Higher frequencies : Details
- Required sampling rate lower for low frequency image (lower number of pixels, lower resolution)



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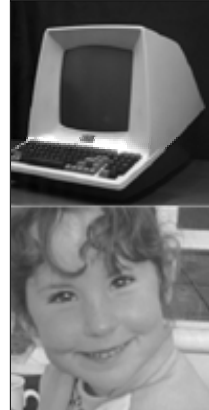
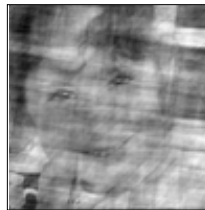
## Amplitude

- Amplitude
  - **How** much details?
  - Sharper details signify higher frequencies
  - Will deal with this mostly



## Phase

- **Where** are the details?
- Though we do not use it much, it is important, especially for perception



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## Reducing Frequency content

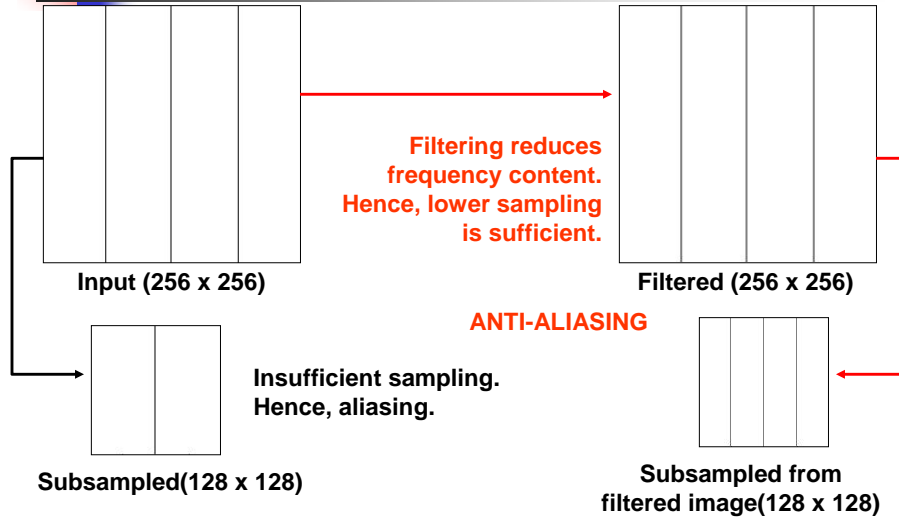
- Filtering: Applying mathematical function over a window around every pixel
  - Simplest: Averaging pixels (Box Filter)
- Other sophisticated methods
  - Size of the window used
  - Mathematical function used is more complicated



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Slide 16

## How does it help?

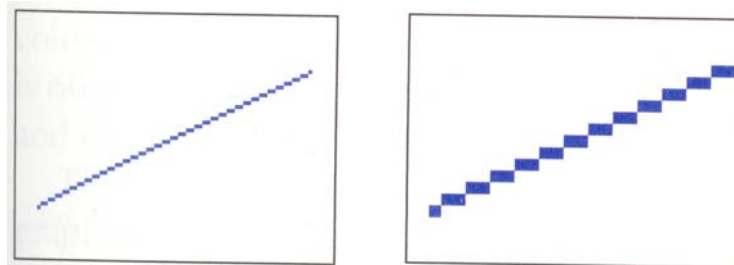


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Slide 17

## Aliasing in Scan Conversion

- Rasterized line segments and edges of polygons look jagged

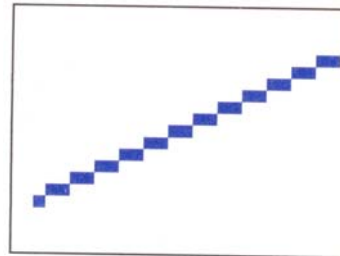
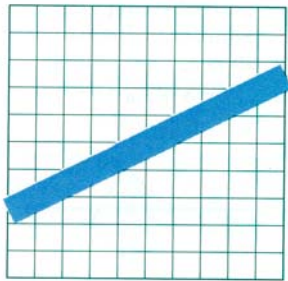


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Slide 18

## Aliasing in Scan Conversion

- 1-pixel wide ideal line span partial pixels
- Scan conversion method forces us to choose exactly one pixel for every value of  $x$

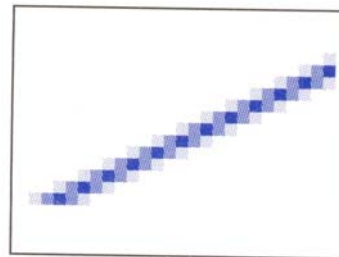
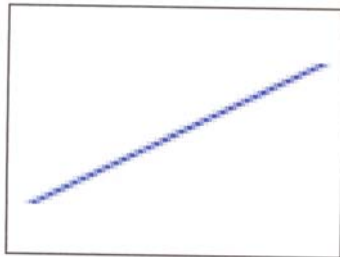


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Slide 19

## Aliasing in Scan Conversion

- **Supersampling and Filtering:** Render a *super-sampled* image and then filter
- **Area Averaging:** Shade each pixel by gray value = the percentage of the actual line crossing it at  $x$

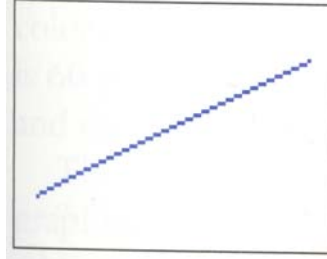
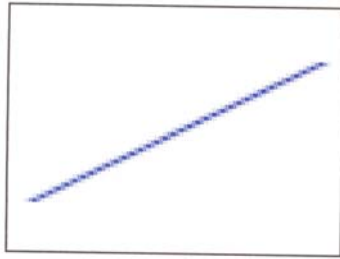


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Slide 20

## Aliasing in Scan Conversion

- Very expensive – Usually not implemented for real-time rendering
- Only when you have lot of time to render each frame – Like in animation movies

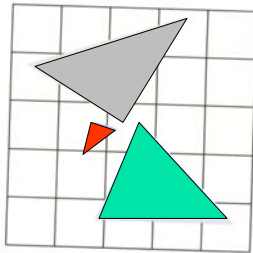


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Slide 21

## Aliasing during z-buffering

- A pixel shared by three primitives
  - Z intersection – *identified in an integer level*
  - Front-most gets drawn



- Same technique: Area weighted average

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# Temporal Aliasing

- Animation
  - Speed of the object too fast
  - Jittered Motion

