Image Pyramids

Computer Vision (CS0029)

Image Pyramid

- Multi-resolution image representation
- Useful for image coding/compression

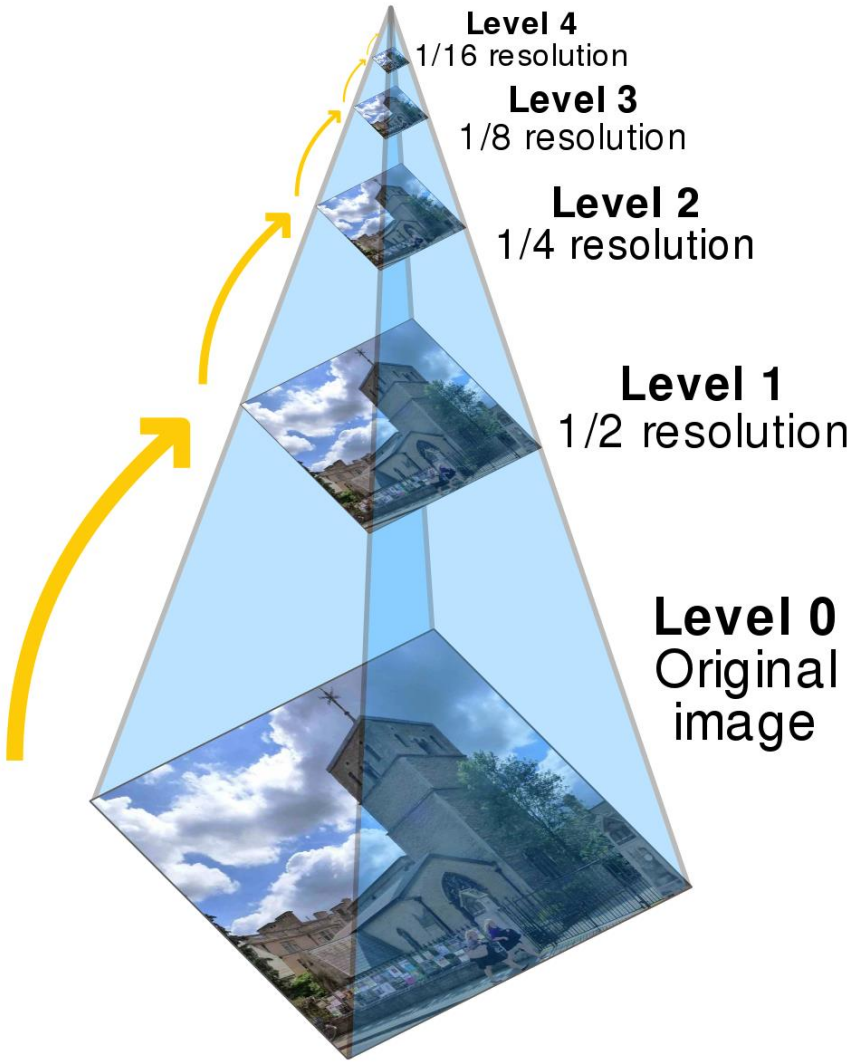


Image Pyramids Operation: Theory

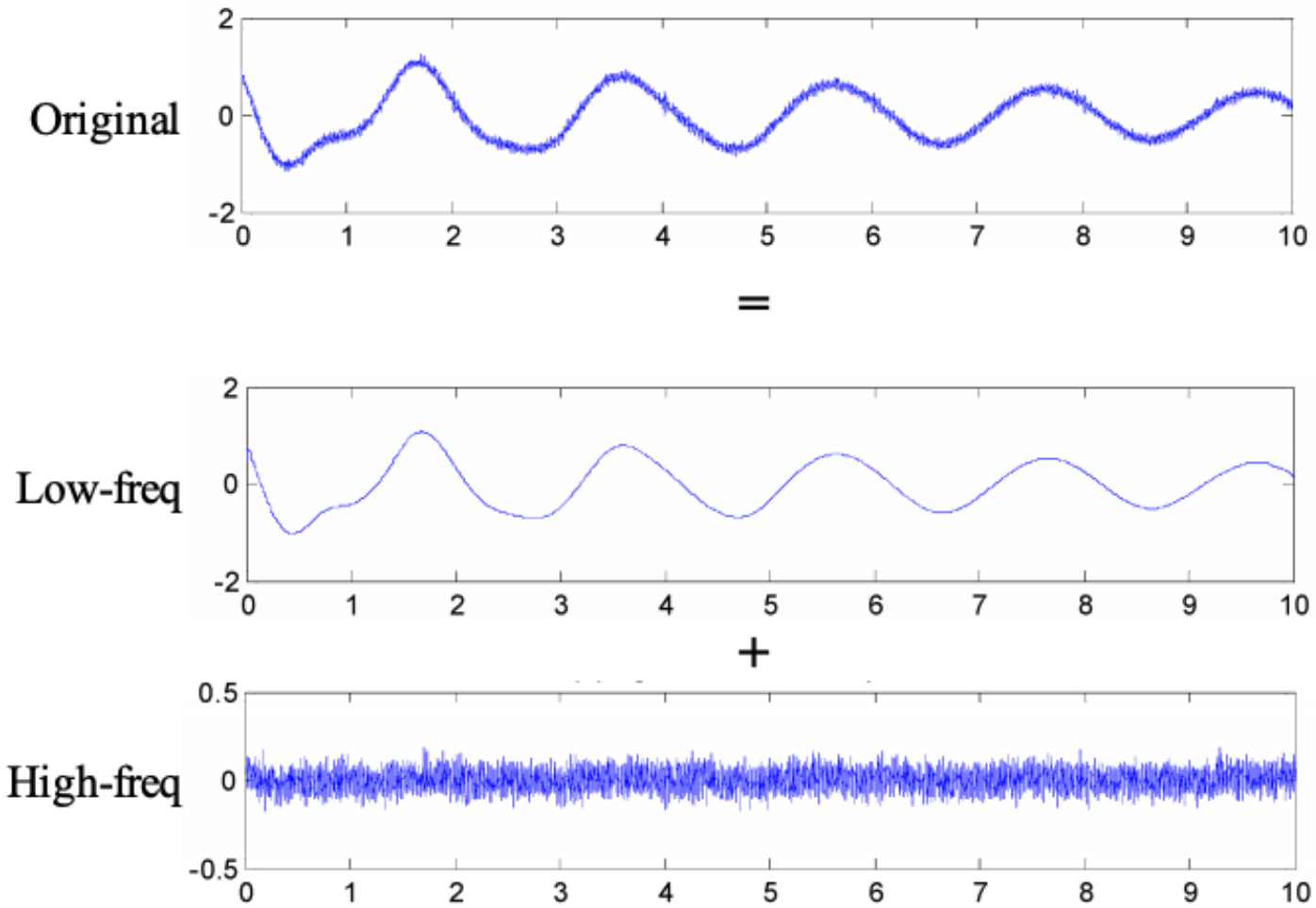
- Two fundamental operations
  - Approximately inverse of one another
  - Linear operations
- First operation: blur and sample the input image (create the pyramid)
- Second (reverse) operation: interpolate the blurred and sampled image to estimate the original
- First examine 1-D signal, then move on to images

Blurring/Sampling Operation

- First operation convolves input signal with a smoothing kernel, then samples the result
  - Blurring and sampling go together
- Blurring creates smoother version of original (reducing aliasing), containing fewer high-frequency components
- Thus can represent blurred data with fewer samples than in original
  - Sample blurred signal at every other value

- Original signal = Low-frequency + high-frequency info

Visualization

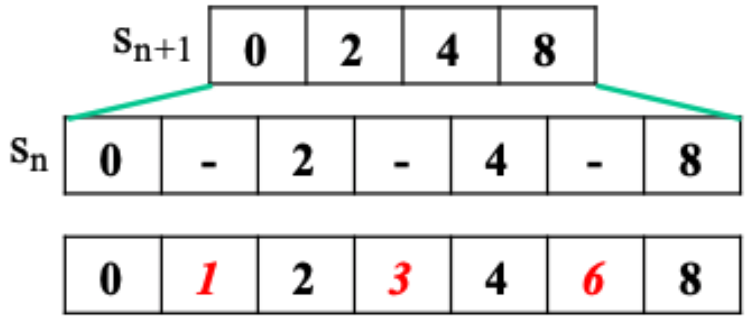


Pyramid Construction

- To create pyramid, repeat blurring and sampling on each resulting signal
  - Original signal s_1
  - Blur and sample s_1 to create s_2
  - Blur and sample s_2 to create s_3
  - And so on…
- Each successive level contains half as many sample values as the previous level
  - For an image, sampling every other row and column, each successive level contains one-quarter of the samples as the previous level

Interpolation (Reverse) Operation

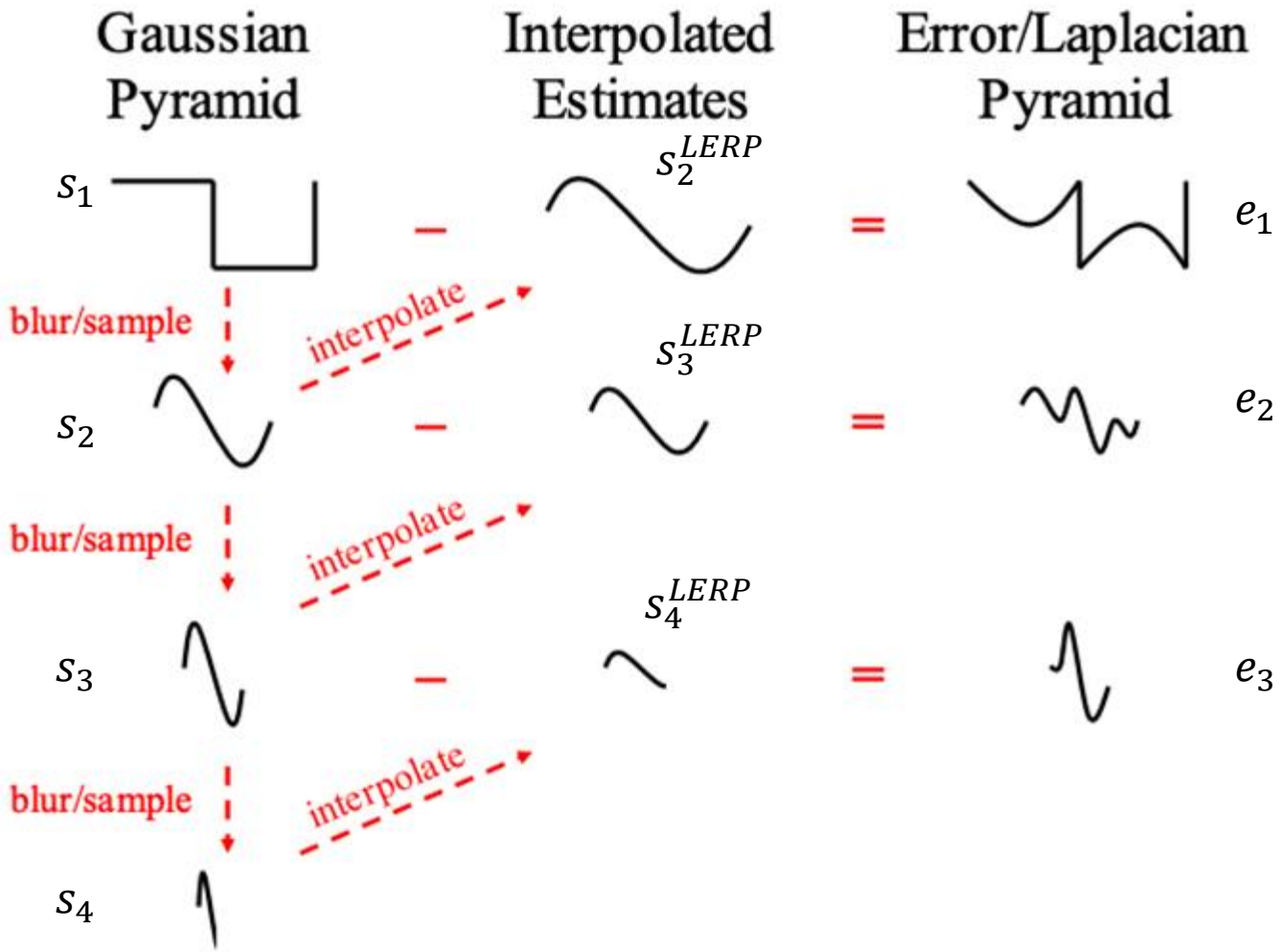
- Approximate inverse of blurring/sampling operation
- Make an informed guess of original signal from the reduced signal
  - Approximate s_n from s_{n+1}
- First up-sample s_{n+1} to size of s_n
  - Place data from s_{n+1} into every other entry of a vector s_n
- Next interpolate new empty values between the given values
  - For example use the average of the given neighbor values



Error Signal as Laplacian Pyramid

- Error is difference between estimate (low-frequency) and original
  - Interpolated estimate and original
- Sequence of error signals forms the “error pyramid”
  - This error pyramid is called a Laplacian pyramid
- From error pyramid, we can reconstruct original signal s_1 **without any error**
  - Add interpolated s_2 and the error e_1
    - Error e_1 is the difference between s_1 and the interpolated s_2 to (s_1)
    - Low-frequency (s_2) + high-frequency (e_1)

1-D Pyramid Construction



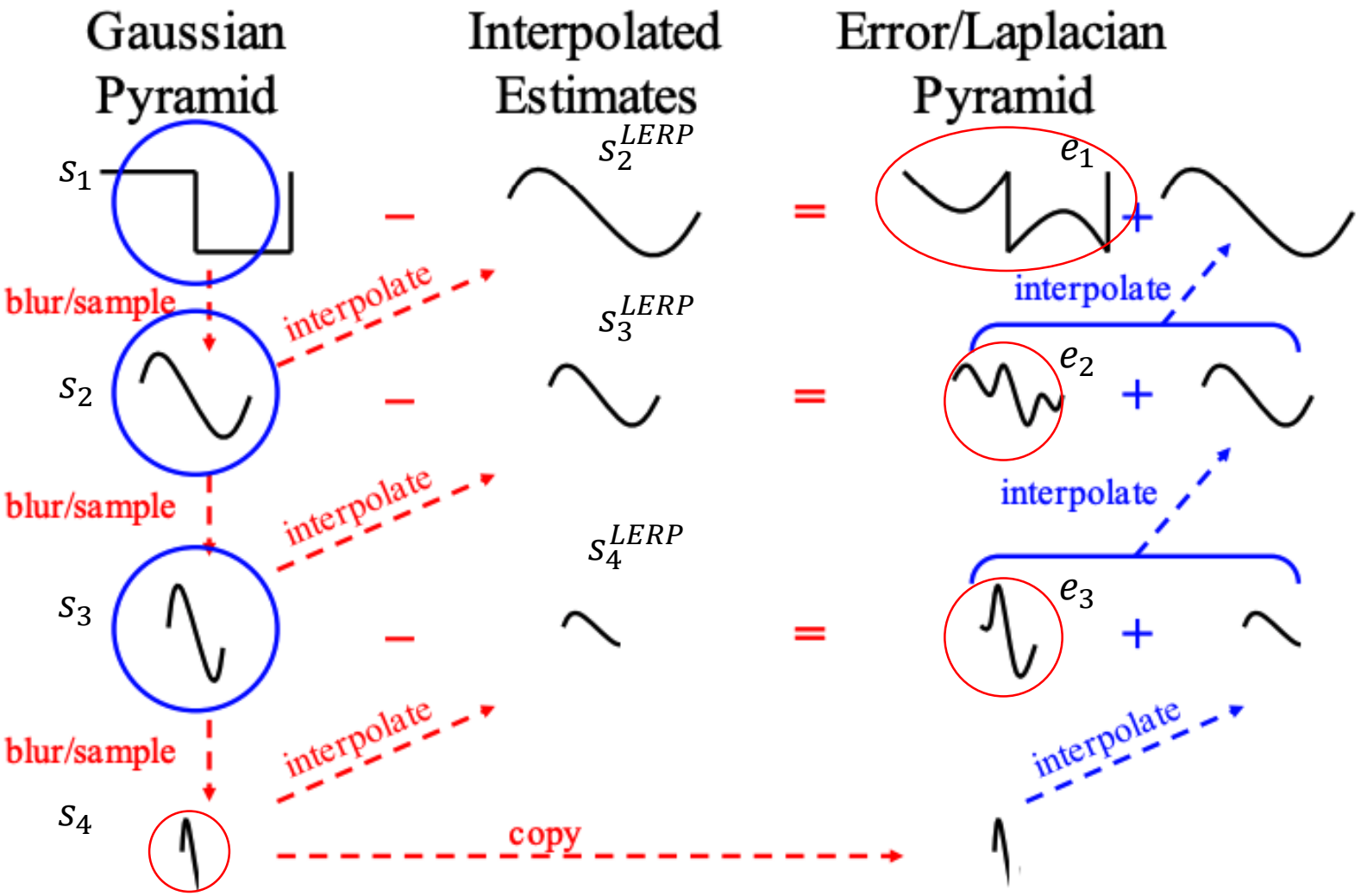
Reconstruction

- Original signal can be recovered exactly by interpolation, then summing all the levels of the error pyramid

- Hence, only the **error pyramid** is needed to represent the original signal completely

- Why do this?
  - Useful for coding/compression

1-D Pyramid Reconstruction



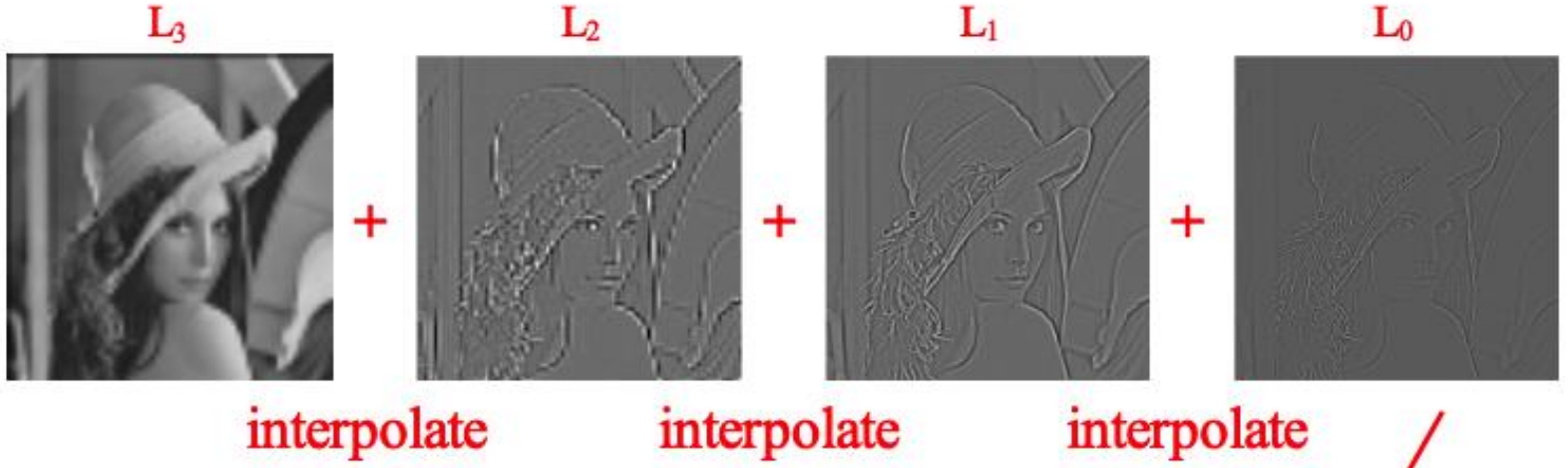
Image

- No previous principles change when processing 2-D images
- Use Gaussian blurring (filtering)
  - $G(m,n) = w(m)w(n)$
  - where $w = [0.25 - 0.5a, 0.25, a, 0.25, 0.25 - 5a]$
- Sub-sample rows and columns
- Useful for image coding
- Applicable to progressive transmission

Gaussian Pyramid

Error Pyramid

Reconstruction



Original

Compression and Coding

- Could just code the original image
  - But histogram of values is broad (not well suited to compression method)
- Error pyramid is useful
  - Multi-resolution representation of image
  - Information varies as descend in resolution
- Error signals are distributed over smaller range (around 0) than original image
  - Easier to compress (more compact) in lossless/lossy method
  - Can be represented very efficiently
- Quantization of error distribution further reduces data without perceptual loss
  - Divide range of pixel values into bins

Image Coding/Compression

Original

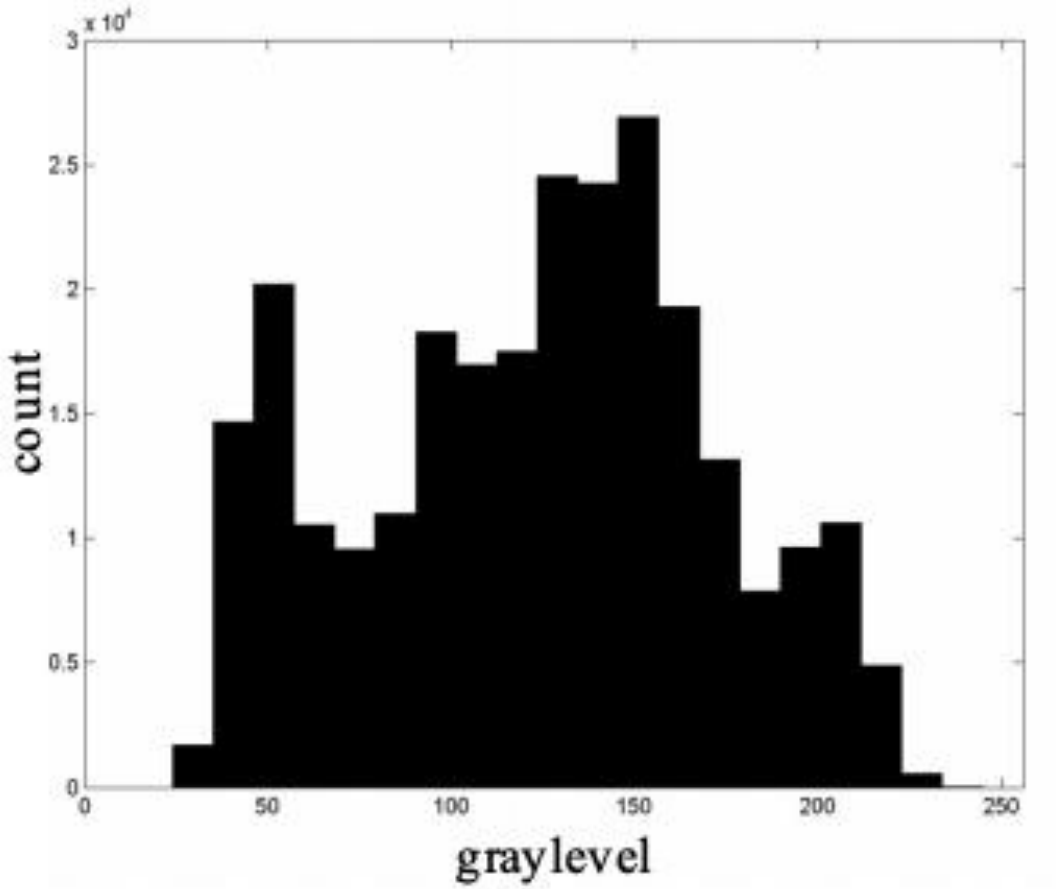
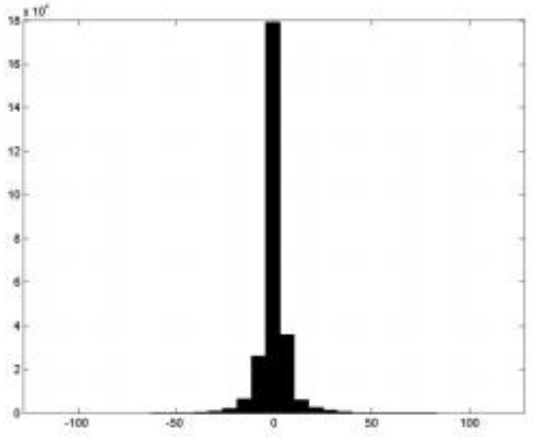
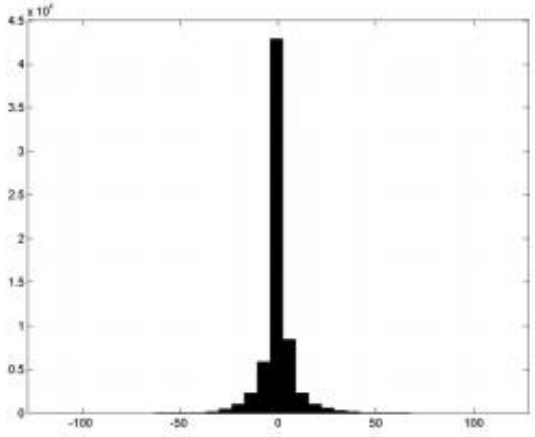


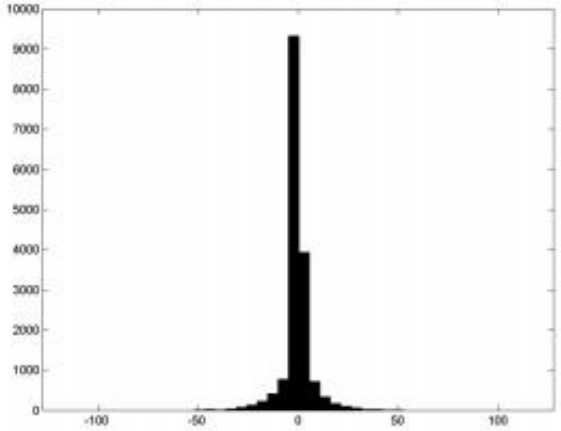
Image Coding/Compression



L_0



L_1



L_2

Progressive Transmission

- Progressive image transmission
  - Coarse rendition of image sent first to give early impression of image content
  - Further transmissions provide image detail of progressively finer resolution
  - Can terminate transmission when user sees enough details
- Laplacian pyramid well suited for progressive image transmission
  - Topmost level of pyramid sent first (low resolution image)
  - Next lower level is then transmitted and added to the first, and so on
- On receiving end, see image steadily coming into focus

Progressive Transmission

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