Outline
• Image pyramid:
  • Approximation pyramid
  • Prediction residual pyramid
• Subband coding
  • 1D & 2D subband analysis
• Applications of multiscale processing
  • Laplacian pyramid blending
  • Multiscale edge detection

Image Pyramids
• A collection of decreasing resolution images arranged in the shape of pyramid
  • The base of the pyramid contains a high-resolution image
  • Both size & resolution of the image decrease as you move up to the top
• Base 2 image pyramid:
  • Resolution at base level is \( N \times N \) \( (N = 2^k) \)
  • Total pixels in a fully populated pyramid
    \[ N^2 + \left( \frac{N}{2} \right)^2 + \left( \frac{N}{4} \right)^2 + \ldots + 4 + 1 \leq \frac{5}{3} N^2 \]

Approximation Pyramid
• The original image is kept at the base of the pyramid
• Images in upper level of the pyramid are the coarse approximations of the original image
  • Image at level \( k-1 \) is calculated using the image at level \( k \):
    • Filter the image first, before downsampling it
  • Different filters can be used:
    • Mean filter \( \rightarrow \) Mean pyramid
    • Low-pass Gaussian filter \( \rightarrow \) Gaussian pyramid
    • No filter \( \rightarrow \) Sub-sampling pyramid (aliasing)

Prediction Residual Pyramid
• Top of the pyramid stores a low-resolution approximation of the original image
• Lower levels keep information for reconstructing the original image from low-resolution versions
  • Level \( k \) prediction residual is calculated by:
    • Create a prediction by upsampling the approximation at level \( k-1 \) and filtering the result
    • Compute the difference between the prediction and the approximation at level \( k \)
  • Prediction residual pyramid can be efficiently coded as most differences are close to zero
**Subband Coding**

- Decompose an image into a set of band-limited components (subbands)
  - Each subband is generated by bandpass filtering the input
  - The subbands can be downsampled without loss of information
- The subbands can be reassembled to reconstruct the original image without error
  - Reconstruction is accomplished by upsampling, filtering, and summing the individual subbands

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**1D Subband Analysis and Synthesis**

- Average
- Low-pass filter
- High-pass filter
- Smoothing filter
- Analysis

- Difference
- Smoothing filter

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**2D Subband Analysis**

- Low-pass filter
  - Rows
- High-pass filter
  - Columns
- Low-pass filter
- High-pass filter

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**Applications of Multiscale Processing**

- Improve search
  - Template matching over different scales to find faces of different resolutions
- Preprocessing:
  - Texture mapping in computer graphics needs to access image at different blur levels
- Image Processing
  - Edit frequency bands separately
  - Laplacian pyramid blending
**Manual Image Blending**

**Feathering**
- Generate weight maps using distance transform
- Blend the 2 images using weighted average

**Laplacian Pyramid Blending**
- Pseudocode:
  - Build Laplacian pyramids $L_A$ & $L_B$ from images A & B
  - Build Gaussian pyramids $G_A$ & $G_B$ from the masks
  - Compute a combined pyramid $L_C$ from $L_A$ & $L_B$ using $G_A$ & $G_B$ as weights
  - $L_C(p,q) = \frac{G_A(p,q) \times L_A(p,q) + G_B(i,j) \times L_B(i,j)}{G_A(p,q) + G_B(i,j)}$
  - Collapse the $L_C$ pyramid to get the blended image
  - Upsample the higher level image then add the result to the lower level one

**Multiscale Edge Detection**