Multiscale Processing

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

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 and 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^J)
  - Total pixels in a fully populated pyramid

\[ N^2 + \left( \frac{N^2}{2} \right) + \left( \frac{N^2}{4} \right) + \Lambda + 4 + 1 \leq \frac{4}{3} N^2 \]

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 j-1 is calculated using the image at level j:
    - Filter the image first, before downsample it
  - Different filters can be used:
    - Mean filter -> Mean pyramid
    - Low-pass Gaussian filter -> Gaussian pyramid
    - No filter -> 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 j prediction residual is calculated by:
    - Create a prediction by upsampling the approximation at level j-1 and filtering the result
    - Compute the difference between the prediction and the approximation at level j
- Prediction residual pyramid can be efficiently coded as most differences are close to zero

Approximation & Prediction Model
**Approximation & Prediction Residual Pyramids**

- 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**

- Low-pass filter
- High-pass filter
- Smoothing filter

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**2D Subband Analysis**

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

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**Subband Coding Examples**

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**Subband Coding Examples (Cond’t)**
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

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

Blending Example

Multiscale Edge Detection