Spatial image operations

CS 417 Lecture 6

Overview

- End of raster image topic
- Resampling images
  - scaling
  - rotating
- Warping images
  - morphing
- Filtering images
  - using discrete convolution

Reducing and enlarging

- Very common operation
  - devices have differing resolutions
  - applications have different memory/quality tradeoffs
- Also very commonly done poorly
- Simple approach: drop/replicate pixels

Reducing by dropping pixels

Reducing by replicate pixels

Gaussian filter

Box reconstruction filter

Bicubic reconstruction filter
Types of aliasing

- Garden variety
  - what we saw in this natural image
  - fine features become jagged or sparkle

- Moiré patterns

Moiré aliasing

- Regular patterns lead to spikes in FT
- Spikes cause strong aliases at low frequencies
  - must be very thoroughly extinguished to avoid artifacts

Types of aliasing

- Garden variety
  - what we saw in this natural image
  - fine features become jagged or sparkle

- Moiré patterns
  - caused by repetitive patterns in input
  - produce low-frequency artifacts; highly visible

How to resample

- Define function that computes the reconstructed continuous image at any point
  - loop over nearby pixels, average using filter weight
  - this is evaluating the convolution at a point

\[ I_c(x, y) = \sum_{i,j} h(x-i, y-j)I[i,j] \]
Separable filters

- Full reconstruction per sample is simple & flexible
  - but it is $O(n^2, r^2)$
  - expensive if $r$ is large (downsampling)
- Separable filter
  - a convolution of two perpendicular cross sections
- Separable algorithm
  - useful when you are generating sample points on a rectangular grid aligned with the image grid
  - two 1D convolutions

Rotating images

- Can handle rotation using separate reconstructions
  - (in fact arbitrary remapping of plane)
  - but this is very slow again
- Turns out that a rotation can be re-expressed
  - a shear followed by another shear
  - each shear can be done in 1D (columns separately)

Image warping

- Have procedure for sampling at any location
- Define remappings of the plane to create distorted images
- An example: morphing
  - specifically, Beier and Neely’s feature-based warp
  - user marks corresponding feature lines in two images
  - each line alone defines a scaled rotation
  - average them with distance-based weights to get warp
Image filtering

- A direct use of convolution
  - implemented discretely on sampled image
    \[ I'[i, j] = \sum_{i', j'} h[i - i', j - j'] I[i', j'] \]
  - exactly equivalent to continuous \( h \) used at grid points
  - again separable \( h \) leads to efficient two-pass algorithm
  - can compute discrete FT in \( O(n^2 \log n) \) using FFT
    • so for sufficiently large filters that is faster
- Filter design for desired properties in FT: well studied
  - much of image processing is done using linear filters

Raster images wrap-up

- Images are really functions of the continuous plane
- We approximate them with raster images
  - pixels are samples from the underlying image
  - sampling and reconstruction define the “meaning” of pixels
- Regularly sampled representations are prone to aliasing
  - generally blurring at the appropriate place is the solution
- Signal processing theory shows us what to do
  - Nyquist limit: no frequencies past \( f_s / 2 \) can be represented
  - Need to extinguish those frequencies in two places
    • during sampling and during reconstruction