

SYDE 575: Introduction to Image Processing

Bilateral Filtering

Recap: Spatial smoothing filters

- All of the filters discussed so far are spatial smoothing filters
- Weight of each pixel in the neighborhood covered by the filter depends on the proximity of the pixel to the center pixel being filtered
 - The closer the pixel is to the center pixel, the higher the weight

Range smoothing filters

- Problem: oversmooths edges and other fine image detail
- Alternative solution: range smoothing filters?
- Weight of each pixel in the neighborhood covered by the filter depends on the similarity of the pixel's intensity value to that of the center pixel being filtered
 - The closer the pixel's intensity value is to that of the center pixel, the higher the weight

Range smoothing filters

$$g(x, y) = \frac{\sum_{N} h(|f(x, y) - f(x_c, y_c)|) f(x, y)}{\sum_{N} h(|f(x, y) - f(x_c, y_c)|)}$$

range smoothing weight input

neighborhood

Bilateral filtering

- Problem: simply remaps intensity values
 - No notion of space
 - Poor noise reduction performance (in fact, not really useful by itself)
- Idea: Combine spatial smoothing filters with range smoothing filters!
 - Good noise reduction (Spatial smoothing)
 - Good edge and detail preservation (Range smoothing)

Bilateral filtering

- Resulting filter is non-linear

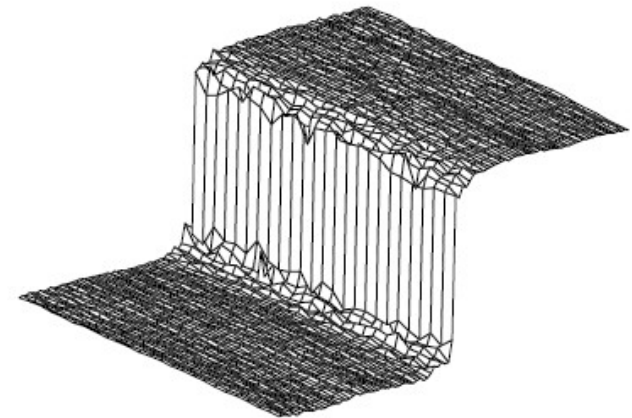
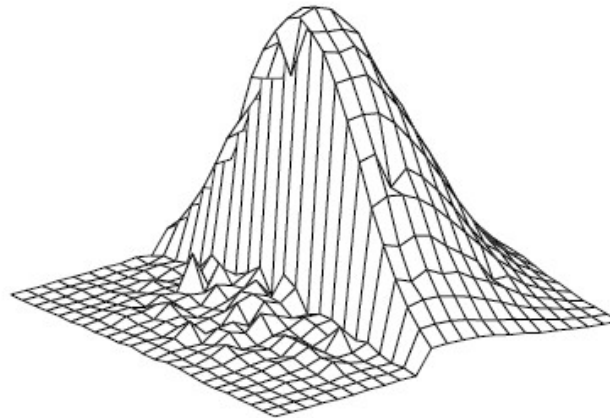
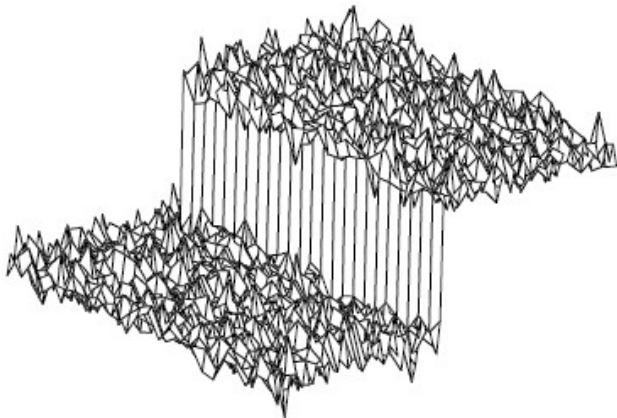
$$h_{bf} = h(|f(x, y) - f(x_c, y_c)|)h(|x - x_c|, |y - y_c|)$$

Spatial smoothing filter

Range smoothing filter

Example

- Suppose we use Gaussian models for the range and spatial smoothing filters



Uses: Noise suppression



noisy



Gaussian spatial filter



Bilateral filter

Uses: Special Effects

- Bilateral filter reduces small image details while preserving large edge details
- What would happen if we apply bilateral filtering multiple times?
 - More and more smaller details get smoothed out
 - Large edges remain well-preserved
- Result: cartoon-like image

Uses: Special Effects



original



5 iterations