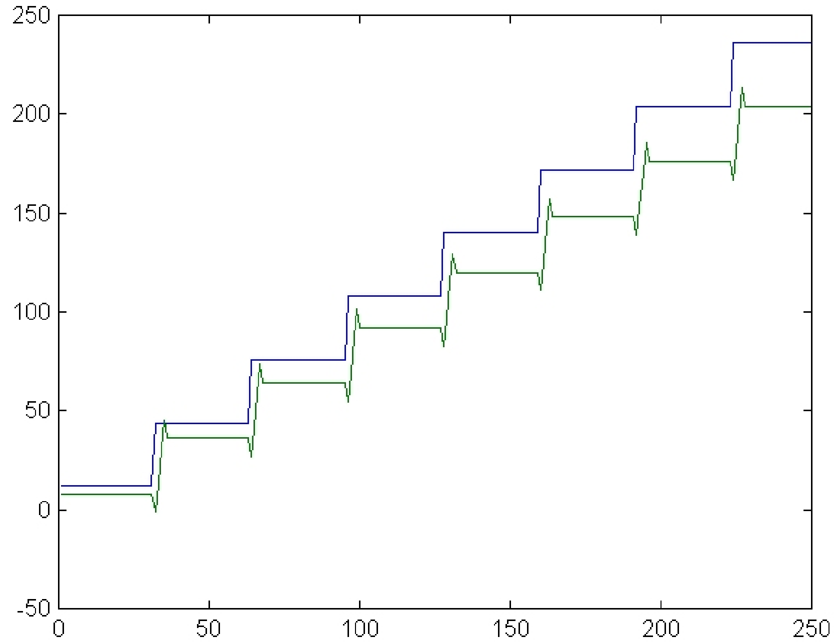
Summary of Lecture 9

- In lecture 9 we learnt about the Gibbs phenomenon.
- We learnt edge detection with:
  - Gradient operators based on first derivatives and associated local maxima.
  - Gradient operators based on second derivatives and associated zero crossings.
- We learnt about Mach bands and the low-pass nature of the human visual system

Low-pass Response of the Human Visual System



- The human visual system low-pass filters the scenes under observation.

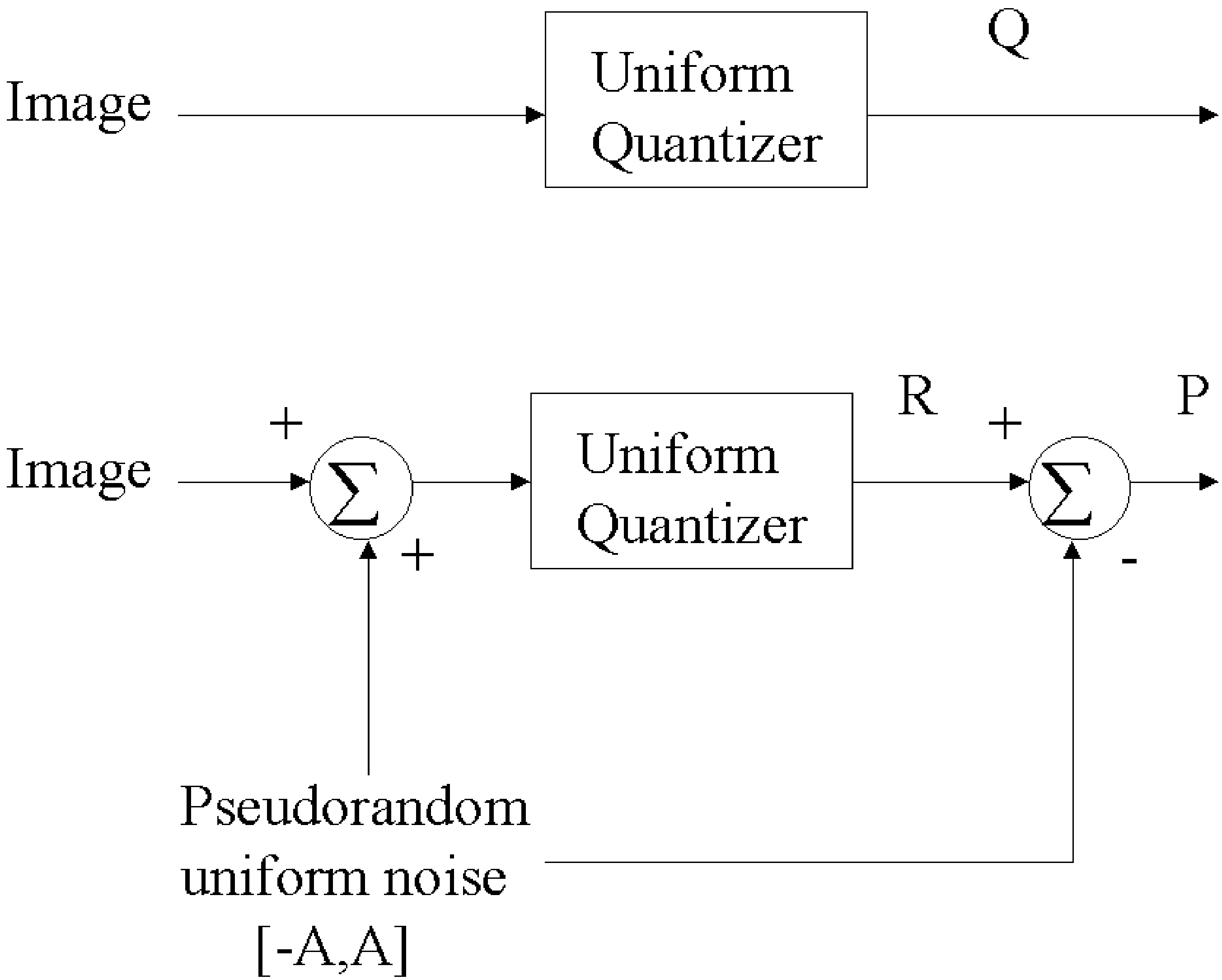
"Perceptual" Image Processing

- The human visual system has a low-pass response, i.e., humans viewing a certain image do not fully see some of the "details" that manifest themselves at high frequencies.
- Note that low-pass filtering $\sim$ averaging.
- We will take advantage of this by pushing certain processing errors to high frequencies where humans cannot see them.
- Perceptual image processing assumes that the results of the processing will be viewed by humans. Processing techniques are geared toward this particular assumption.
- Perceptual image processing results are good for subjective evaluations and they are usually not good for objective evaluations (such as mse).

Quantization and False Contours

We already know that coarse quantizers produce false contours in the quantized image which appear unpleasant to the human observer.

Pseudo-random Noise Dithered Quantization



Pseudo-random Noise Dithered Quantization contd.

- In regions of smoothly varying pixels we usually get false contours after coarse quantization.
- With noise dithered quantization, the additive noise causes pixel values in these regions to go below or above the quantization threshold, thereby breaking the contours.
- A is chosen such that only the least significant bit is affected in the quantization.

Example

Q (Δ= 32)

R (A=32)

P (A=32)

Example

Q (Δ= 64)

R (A=48)

P (A=48)

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Example

Q (Δ= 128)

R (A=48)

P (A=48)

Image Halftoning

- Some display devices like printers can only display black or white pixels, i.e., when an image is printed it undergoes very coarse quantization.
- These devices compensate for this limitation by having the ability to display many pixels or "dots" in very small areas.
- The type of halftoning algorithms we are interested upsample an image, add pseudo random noise and quantize the result to two levels (i.e., obtain $\mathbf{R}$ using an upsampled image.) Please see the textbook pages 120-122.

Image Warping and Special Effects

Let $A(i,j)$ be an image.

- In image warping our aim is to generate an image $B(k,l)$ from $A(i,j)$ where

$$B(k,l) = A(x(k), y(l))$$

- We will call $x(\ldots)$ and $y(\ldots)$ the pixel warping functions.
- In the following slides we will generate images $\mathbf{B}$ from $\mathbf{A}$ using different warping functions.
- There are two special cases:
  1. $x(k), y(l)$ is out of the "boundaries" of $\mathbf{A}$. In this case we simply set $B(k,l) = 0$.
  2. One or both of $x(k), y(l)$ are not integers. In this case we simply find the nearest two or four pixels in $\mathbf{A}$, average the corresponding pixel values to obtain $B(k,l)$. (We can also do rounding).

Translation and Rotation

B translation

B rotation

Translation: $x(k,l) = k + 50; y(k,l) = l;$

Rotation: $x(k,l) = (k - x_0)cos(\theta) + (l - y_0)sin(\theta) + x_0;$

$$y(k,l) = -(k - x_0)sin(\theta) + (l - y_0)cos(\theta) + y_0;$$

$x_0 = y_0 = 256.5$ the center of the image $\mathbf{A}$, $\theta = \pi/6$

“Wave”

wave 1

wave 2

wave2: $x(k,l) = k + 20sin(\frac{2\pi}{128}l); y(k,l) = l;$

wave2 : $x(k,l) = k + 20sin(\frac{2\pi}{30}k); y(k,l) = l;$

“Warp” and “Swirl”

$$\text{warp}: \quad x(k,l) = \text{sign}(k-x_0)/x_0 * (k-x_0)^2 + x_0; y(k,l) = l;$$

$$\text{swirl}: \quad x(k,l) = (k-x_0)cos(\theta) + (l-y_0)sin(\theta) + x_0;$$

$$y(k,l) = -(k-x_0)sin(\theta) + (l-y_0)cos(\theta) + y_0;$$

$$r = ((k-x_0)^2 + (l-y_0)^2)^{1/2}, \;\; \theta = \pi/512 \; r$$

$x_0 = y_0 = 256.5$ the center of the image **A**

“Glass”

$$x(k,l) = k + (rand(1,1) - .5) * 10;$$
$$y(k,l) = l + (rand(1,1) - .5) * 10;$$

Median Filtering

A

B Median Filtered

Define the set $Z(i,j) = \{A(m,n) | i - W \leq m \leq i + W,\ j - W \leq n \leq j + W\}$. Then $B(i,j) = median(Z(i,j))$.

Oil Painting

Define the set $Z(i,j) = \{A(m,n) | i-W \leq m \leq i+W,\ j-W \leq n \leq j+W\}$. Then $B(i,j) =$ the most frequent value in $Z(i,j)$.

Homework X

1. Implement the pseudo random noise dithered quantizer with $\Delta = 32,\ 64,\ 128$. In each case try to choose the "best" possible noise parameter A.
2. Implement the warping functions for translation, rotation, wave, warp, swirl and glass. Try to use different parameters. My parameters x_0, y_0, etc., are set for a 512×512 image.
3. Implement the median filter for your image. First randomly pick 4000 pixels and set their values to zero to obtain a pepper noise corrupted image. Then apply the median filter with $W = 3$. Repeat with 40000 pixels corrupted. What can you do to improve results now? (Hint: Try increasing W and/or running several iterations of the median filter.)

References

[1] A. K. Jain, *Fundamentals of Digital Image Processing.* Englewood Cliffs, NJ: Prentice Hall, 1989.