SGN-12006 Basic Course in Image and Video Processing

Final Exam KEY – 26/1/2017

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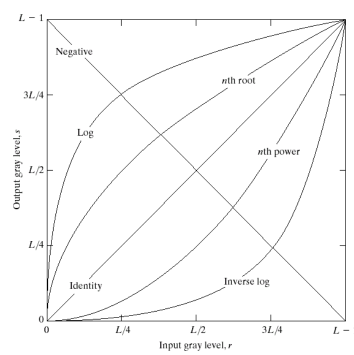
Instructions: This is a closed-notes and closed book exam. **FACULTY APPROVED CALCULATORS ARE ALLOWED. Exam papers must be returned.** Please do not talk to anyone during the exam. If you get caught cheating, your exam paper will be confiscated, you will fail the course and your action will be dealt with according to TUT Code of Honor. **Answer the questions in the space provided and use the back of the page if needed. Additional papers WILL NOT be graded. Exam proctor: Collect all the exam papers! Do not accept additional pages!**

Problem 1. (12 points)

Briefly explain the role and usefulness of each type of transformation in the plot below in image enhancement?

FIGURE 3.3 Some basic gray-level transformation functions used for image enhancement.



Answer: Identity: does nothing

Negative: produces the negative of an image. It can be useful, e.g. in viewing mammograms

Log: is a logarithm transformation. It maps a narrow range of low gray-level values in the input image into a wider range of output levels and vice versa for the higher values of the input levels. It expands values of dark pixels in an image while compressing the higher-level values.

Inverse log: is the inverse logarithm transformation. It does the opposite of what the log transformation does.

Nth root: is power-law transformation (with power smaller than 1). It maps a narrow range of dark input values into a wider range of output values.

Nth power: is a power-law transformation (with power greater than 1). It has the opposite effect of the nth root.

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Problem 2 (15 points):

What is the type of the following filters (lowpass/highpass/bandpass) and why?

$$\frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

(a)

$$\frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

(b)

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

(c)

Ans:

The first is a low-pass filter because it smoothens the output intensity value by using the values of the pixel's neighbors. (5 points)

The second is a low-pass filter because it smoothens the output intensity value by using the values of the pixel's neighbors. (5 points)

The third one is a high-pass filter because it calculates the difference of the intensities in the neighborhood of a pixel (edges). (5 points)

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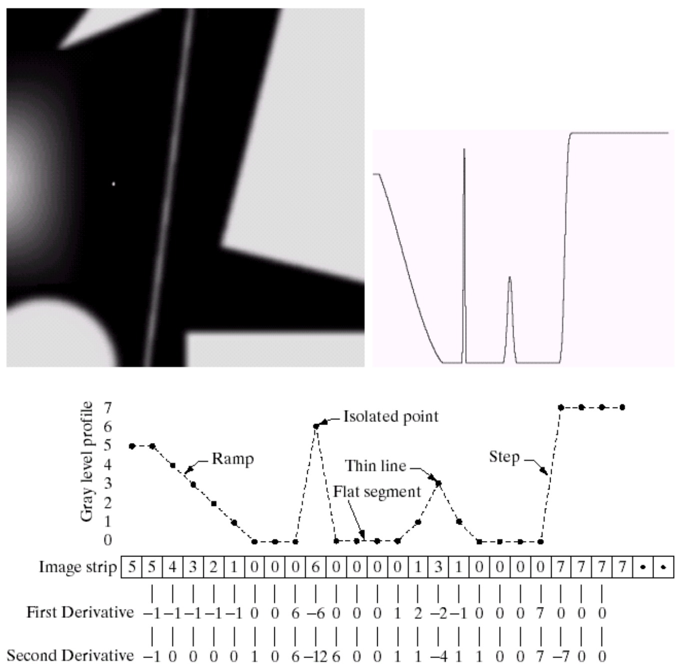
Problem 3. (10 points)

Reference to Figure 3.38 below, discuss the properties of the first and second order derivatives with respect to edges, steps, details, lines and isolated points. Which operator is more useful in image enhancement?



a b
c

FIGURE 3.38 (a) A simple image. (b) 1-D horizontal gray-level profile along the center of the image and including the isolated noise point. (c) Simplified profile (the points are joined by dashed lines to simplify interpretation).

Answer:

- **First order derivative**
  - produces thicker edges (2 points)
  - has stronger response to grey-level steps (2 points)
- **Second order derivative**
  - has a much stronger response to details (1 point)
  - produces a double response at step changes in grey level (1 point)
  - has a stronger response to a line than to a step and to a point than to a line. (1 point)
- **Conclusion**
  - Second derivative is more useful to enhance image details (3 points)

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Problem 4. (15 points)

Consider the following adaptive, local noise reduction filter:

$$\hat{f}(x,y) = g(x,y) - \frac{\sigma_\eta^2}{\sigma_L^2}\left[g(x,y) - m_L\right]$$

where $\hat{f}$ is the filter output, g(x,y) is the degraded image to be restored, σ_η^2 is the variance of the noise, σ_L^2 is the local variance of the pixels in a local neighborhood S_{xy}, and m_L is the local mean of the pixels in S_{xy}. **Discuss the behavior** of the filter (a) when there is no noise, (b) when the local area contains important details, e.g. edges, and (c) when the local area is smooth.

Answer:

(a) If σ_η^2 is zero, the filter returns the value of g(x,y). This is the trivial zero-noise case in which f(x,y)=g(x,y).

(b) if the local variance is high relative to σ_η^2, the filter returns a value close to g(x,y). A high local variance is typically associated with edges and these should be preserved.

(c) When the local area is smooth, the two variances would be equal and the filter returns the arithmetic mean of the pixels.

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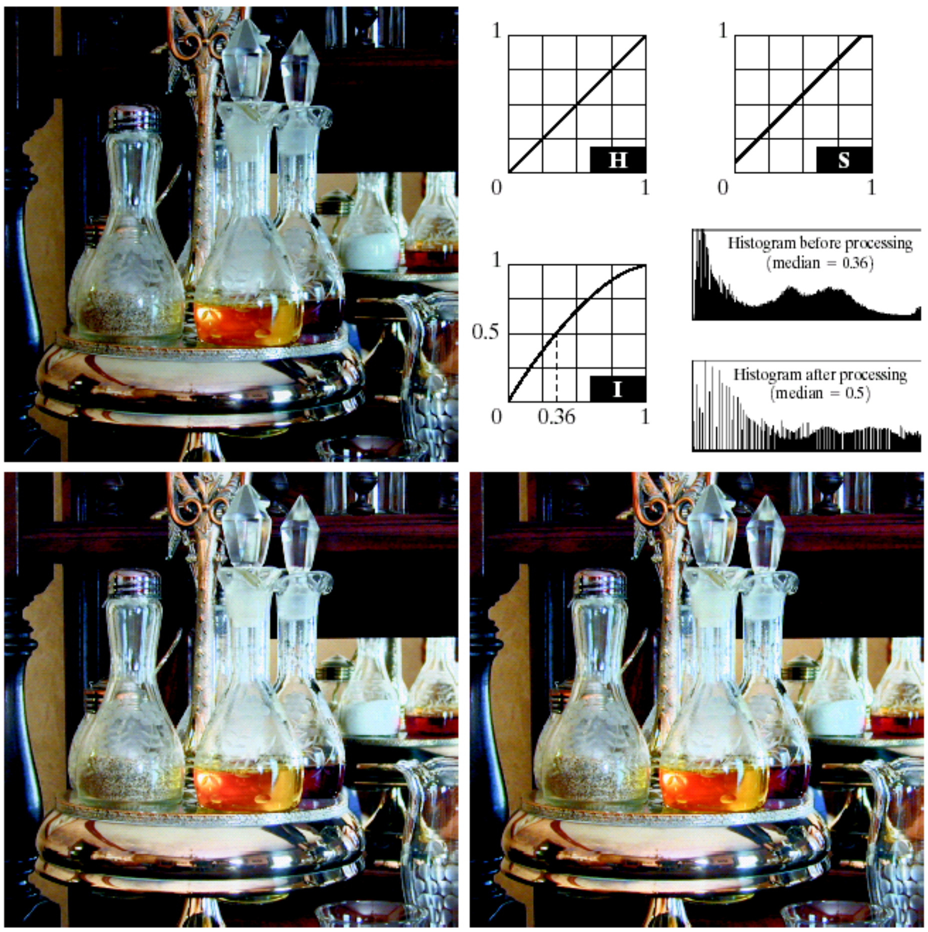
Problem 5. (8 points)

Explain what is done and why in Figure 6.37 below. In particular, explain parts a)-d) in the figure. (hint: in part d) think about the color component that needs to be adjusted in order to compensate for the changes in intensity)



a b
c d

FIGURE 6.37 Histogram equalization (followed by saturation adjustment) in the HSI color space.

Answer: This is a color histogram equalization example.

a) is the original color image (1 point)
b) histogram equalization operation in HSI: H is kept unchanged in order to preserve colors, I is enhanced through a grey-level transformation (e.g. n'th root) in order to make darker objects lighter; and S is slightly adjusted to compensate for changes in the intensity component. (3 points)
c) result of equalizing the I component only; colors have changed slightly due to changes in the intensity. (2 points)
d) result of adjusting the saturation component in order to compensate for the changes in intensity. (2 points)

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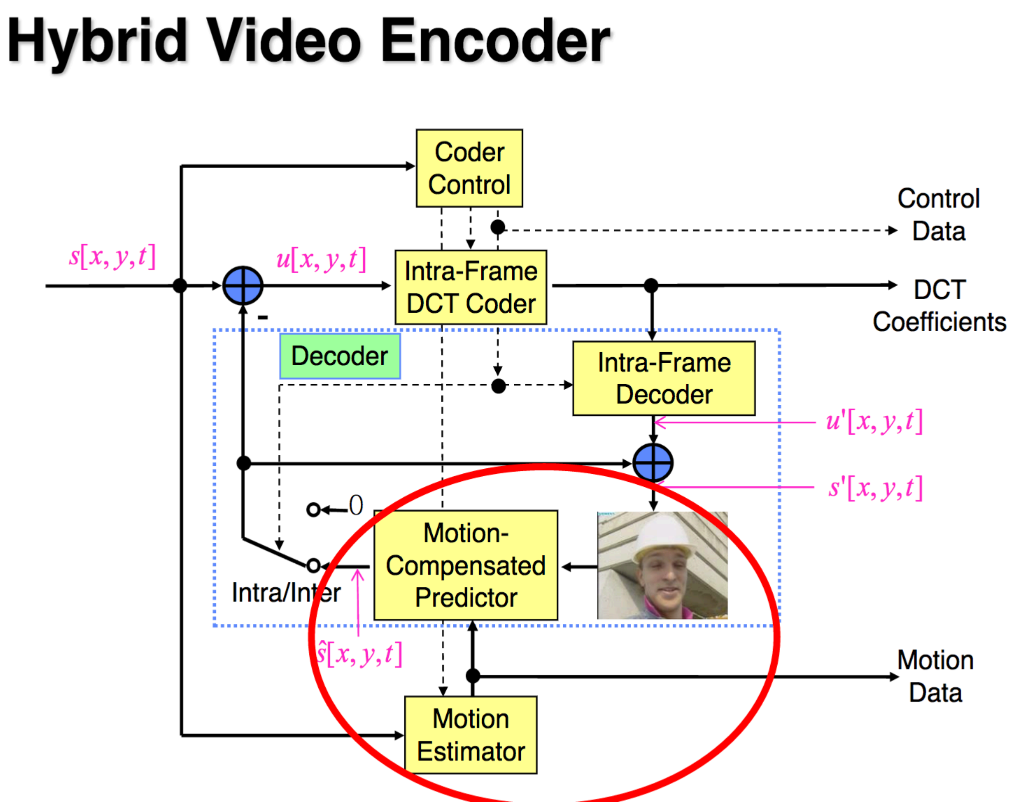
Problem 6: (15 points)

(6.1) Draw a typical hybrid video encoder block diagram (5 points). (6.2) Briefly explain the main function of each block (5 points). (6.3) Explain the concept of motion compensated prediction in the context of hybrid video coding. (5 points)

Answer: (6.1)



(6.2) The difference between the current input macroblock and motion compensated version of it in a reference frame is quantized and DCT transformed and the transform coefficients as well as the motion vectors (plus any additional control data) are sent to the decoder. The difference signal is de-quantized and inverse DCT transformed, motion compensated and subtracted from the current macroblock input. Motion compensation can be applied in intra or inter mode. Motion estimation can use e.g. block matching algorithm.

(6.3) In motion-compensated prediction, the encoder searches for a portion of a previous frame which is similar to the part of the new frame to be transmitted. Motion-compensated prediction is a technique used to predict a bloc of pixels in a video, given the previous and/or future frames by accounting for motion of the camera and/or objects in the video.