Exam: Introduction to Image Processing - Part I
October 2, 2014 - 8:30 – 10:30

Student name: ___________________________ Student number: ___________________________

- Put your name and student number on all of the papers you hand in.
- Explain your answers. Simple answers such as yes and 4 will not be given any credit.
- For the images shown, brighter gray values correspond to higher pixel values.
- Fill in the answers in the boxes provided. Dutch or English are both fine.
- You are not allowed to use any other materials but a pen. So no reader, slides, phone, etc.
- Hand over the exam with your answers when you leave. Show your student ID card.
- You are free to leave at any moment after 9:00.
- The total number of points is 50.
- Good luck!

**Question 1:** (3 points) State Weber’s law. Give an example of the law in practice using an image.

**Question 2:** (3 points) A digital image $f$ is sampled at its Nyquist frequency. You may assume the sampling process is ideal. The sampled image is called $g_1$. $f$ is then sampled again (also ideally) at twice the Nyquist frequency. The resulting image is called $g_2$. Describe the differences between $f$, $g_1$ and $g_2$ in terms of (1) image frequency and (2) detail.
**Question 3**: (3 points) Acquisition of an image is often modeled as a convolution process, where the camera (or any imaging device) determines the shape of the convolution kernel. Explain why we usually want this kernel to be very narrow (*i.e.*, we want it to be very close to zero everywhere except in the kernel center).

**Question 4**: (2+2 points) RGB is often not the most convenient color space.

a. Name and explain the main drawback, which is common in practical image processing.

b. In the HSV color model, why does changing the H or S value have no effect when V=0?

**Question 5**: (2+3 points)

a. Which process should we apply to the pixel values when we want to fit an input image with a larger range of pixel values into an image with a smaller range? Just give the name.
b. Which remapping function can be used to ensure that the contrast in the higher pixel values is reduced more than in the lower pixel values? Name the function, and explain what it does.

**Question 6**: (6+4 points) Say that we have a 500 x 500 pixel image, e.g. Figure 1.

a. We apply the kernel in the equation below with a $\sigma$ of 2. This kernel is the two-dimensional rectangular kernel, which produces values of $1/4$ in the area around $(0, 0)$ with a width and a height of 2. What happens when we apply the kernel? Explain your answer in terms of (1) frequency, (2) detail, (3) edges.

$$g(x, y) = \begin{cases} 
\frac{1}{\sigma^2} & \text{if } |x| \leq \sigma/2 \text{ and } |y| \leq \sigma/2 \\
0 & \text{otherwise}
\end{cases}$$

Figure 1: Example picture “Lena”.

b. Which remapping function can be used to ensure that the contrast in the higher pixel values is reduced more than in the lower pixel values? Name the function, and explain what it does.
b. What happens when the $\sigma$ increases? Again, use the same terms to explain your answer.

Question 7: (4+6 points) When not the full range of pixel values is used, one can apply at least two methods two achieved this: (1) windowing and (2) histogram equalization.

a. Explain the differences between the two in terms of the result (contrast, number of distinct pixel values, etc.).

b. Given the histogram in Figure 2, calculate the equalized histogram. Explain the steps taken to arrive at your final answer. You may draw the resulting histogram, or put it in table-form (with clearly x (bin) and y (count) axes indicated).

Figure 2: Histogram with 7 bins.
**Question 8**: (6+6 points) We would like to put the UU logo (Figure 3a) over the Lena image (Figure 1, pixel value range from 0 to 255). The histogram of the logo is given in Figure 4, with values from 0 to 255. Assume that the dimensions (width and height) of both images are the same.

a. Explain how the logo can be put over the Lena image in such a way that everything within the “circle” of the logo covers the Lena image, so the Lena image only shows in the four corners. (This is not Figure 3b.) Describe the steps needed to obtain this composite image (use estimated numbers!).

---

(a) UU logo.  
(b) Output image

Figure 3
b. Explain how the image in Figure 3b can be obtained from Figures 1 and 3a. Again, describe the steps and use (estimated) numbers.

That’s it!