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Week 2 study sheet: Image processing and compositing

Problem 1 (16 points) Convolution filtering can be used to modify images in a variety of ways. . . .

a) (4 points) Explain why the following convolution kernel might be a good choice for smoothing images taken from interlaced video:

$$\begin{matrix} 1 & 1 & 1 \\ 8 & 16 & 8 \\ 1 & 1 & 1 \end{matrix}$$

b) (4 points) Describe the expected effect of filtering an image using the following convolution kernel. Justify your answer.

$$\begin{matrix} -1 & -2 & -1 \\ -2 & 13 & -2 \\ -1 & -2 & -1 \end{matrix}$$

Problem 1 (continued)

c) (4 points) How would you expect the effect to change if instead the following convolution kernel were used?

$$\begin{matrix} -1 & -2 & -1 \\ -2 & 16 & -2 \\ -1 & -2 & -1 \end{matrix}$$

d) (4 points) For the convolution kernel of part (b), if the original image $I(x,y)$ is given as an array of greyscale values, each between 0 and 1, what are the minimum and maximum possible values the filtered image $I'(x,y)$ can take on at a particular pixel?

Problem 2 (16 points)

Linear interpolation is often used to blend two images. Blend fractions α and $1 - \alpha$ are used in a weighted average of each component of each pixel:

$$out \;=\; (1-\alpha)\, in0 \,+\, \alpha\, in1$$

Typically α is a number in the range 0.0 to 1.0. Such an α is commonly used to linearly interpolate two images. What is less often considered is that α may range beyond the interval 0.0 to 1.0. Values above 1.0 subtract a portion of *in0* while scaling *in1*. Values below 0.0 have the opposite effect.

a) (8 points) Suppose we wanted to vary the *brightness* of an image *in1*, using the linear interpolation formula above. What image should we use for *in0*? In this case, what values of α will produce a darkened version of *in1*? What values of α will produce a lighter version?

b) (8 points) Suppose we wanted to vary the *contrast* of an image *in1*, using the linear interpolation formula above. What image should we use for *in0*? What values of α will reduce the image's contrast? What values of α will boost it?

Problem 3 (20 points) A common technique used in special effects work is one in which a *foreground image* (such as that of an actor) is extracted from a background of a constant (or nearly constant) *backing color*—usually blue. The foreground image, along with its *matte*, or alpha channel, can then be composited over a different background. Thus, an actor can be filmed in front of a blue screen and then made to appear as if he or she is in some other environment. This technique is called "blue screen matting," and the computation of the foreground's alpha channel is called "pulling a matte."

While the blue screen matting problem is very difficult in general, there are a number of situations in which *a priori* knowledge of the foreground image colors can make the problem relatively simple. So, let's try pulling some mattes for some of these special cases.

In all of the following notation, you should assume premultiplied alphas for all RGB components; that is, (r, g, b, α) indicates a pixel that is α covered by the color $(r/\alpha, g/\alpha, b/\alpha)$:

- Let $c_k = (r_k, g_k, b_k, \alpha_k)$ be the backing color, which for the rest of this problem we'll assume to be 100% blue, or $(0, 0, 1, 1)$.
- Let $c_f = (r_f, g_f, b_f, \alpha_f)$ be the color of a given pixel in the foreground image, once it is extracted from the backing color.
- Finally, let $c_o = (r_o, g_o, b_o, \alpha_o)$ be the color of that same pixel as it is originally seen by the camera—that is, c_o is the color of the foreground c_f over the backing color c_k. We can assume that every pixel in this image is opaque—i.e., that $\alpha_o = 1$.

In general, c_k and c_o are the "knowns," and c_f is the unknown that we need to solve for. "Pulling a matte" amounts to computing α_f. Once we know α_f, it is easy to solve for the other color components of the foreground image (as you'll show in part (b) below).

Problem 3 (continued)

a) (4 points) Write an expression for c_o in terms of c_f and c_k.

b) (4 points) Express r_f, g_f, and b_f, as functions of α_f and (some or all of) the components of c_o.

Problem 3 (continued)

Now that we know how to compute the various color components of the foreground image once we know its matte, let's pull some mattes for some relatively simple special cases.

c) (4 points) Assume that the foreground image has no blue in it whatsoever—i.e., that $b_f = 0$. What is α_f, expressed as a function of (some or all of) the components of c_o?

d) (4 points) Assume that the foreground is a perfectly grey spaceship—i.e., that $r_f = g_f = b_f$. What is α_f, expressed as a function of (some or all of) the components of c_o?

e) (4 points) Flesh of all races tends to have an RGB color expressible as $[d, , .5d, .5d]$, with d being a lightening factor depending on the individual. Assuming a (flesh-colored) human actor as the foreground element, what is α_f, expressed as a function of (some or all of) the components of c_o?