RECALL LECTURE 5

Thin lens model (camera)

Let $A$ be the aperture size.

$$E(x,y) = L(z) \left( \frac{\text{Area}}{\text{FNR}} \right) \frac{A}{2.}$$

However, what if image is not in focus at $(x,y)$?

We can model the resulting blur with a convolution:

$$E(x,y) \ast G(x,y,\Delta x)$$

This makes sense in regions where $\Delta x$ is approximately constant.

How can we compare blur at different points?

IDEA 1: Heads up! I'm using $I(x,y)$ rather than $E(x,y)$ below.

blur Measure $(x,y) = \sum (I(x,y) - \bar{I})^2$

will be smaller in blurred region

where $\bar{I}$ is mean intensity in that region. The idea is that blurring is averaging, and averaging reduces variance.

The above method often doesn't work however.

The (intuitively) more blurred $\sum$ as the $\sum$ on right.
However, be careful. For any edge, 
\[ \sum_{x} |\frac{d}{dx} I| = \sum_{x} G(x, \sigma_{blur}) = 1 \]
which is independent of the optical blur \( \sigma_{blur} \) if our \( N_{xy} \) covers the whole blurred edge.

So we can't just use the average gradient!

**Intuition:** a blurred edge covers a larger range of \( x \)s.

**IDEA 3** (harder to motivate):

Consider \( \frac{d^2}{dx^2} u(x) * G(x, \sigma_{blur}) = \frac{d}{dx} G(x, \sigma_{blur}) \)

\[ \Rightarrow \sum_{x} \left| \frac{d^2}{dx^2} u(x) * G(x, \sigma_{blur}) \right| dx = 2 \sum_{x} \frac{d}{dx} G(x, \sigma_{blur}) dx = 2 G(x, \sigma_{blur}) \sim \frac{1}{\sigma_{blur}} \]

The sum of second derivatives are much greater for the neighborhood on the right.

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**How to compare blur at different points in a 2D image?**

\[ \sum_{(x,y)} \left| \frac{d^2}{dx^2} I(x,y) * G(x,y, \sigma_{blur}) \right| \]

This convolution is used to reduce noise. Don't confuse it with the optical kernel,

(\( \sigma_{blur} \)) within \( I(x,y) \).

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**Depth from defocus using multiple images**

1. "Accommodation" or "Autofocus" human eye allows for focusing.

2. Vary aperture and shutter speed such that (average) exposure is constant.

3. See Assignment 3, Q1.

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**Assignment 3**

You are given two images,

1. Small aperture and long exposure time
2. Large aperture and short exposure time

Use two images avoids the problematic situation that the underlying texture has spatially varying statistics, ("non-stationary"; "non-homogeneous")

Estimate the blur at each pixel (in the second image).
Small aperture.

Large aperture.

Result