7. Digital camera processing pipeline
Camera processing pipeline

- read image out from sensor — see Sensors lecture
- optional: HDR assembly — see Homework 2
- color balance — see Color lecture
- demosaic
- noise processing
- color matrix — see Color lecture
- tone map
Demosaicking

- First question: how to spell it
  I cite “picnicking”
- Each photosite senses only one color
- We need three measurements at each pixel

http://www.currentprotocols.com/WileyCDA/CPUnit/refId-ns0204.html
Bayer array

- Simple solution: make a half-resolution image
- Want sensor-resolution image? Make up 2/3 of the data!
Half-resolution demosaic

- Idea 1: treat each block of four pixels as a pixel

Easy to code up in one line of Matlab. But what is wrong with this?
Half-resolution demosaic

• Idea 1: treat each block of four pixels as a pixel

Easy to code up in one line of Matlab. But what is wrong with this?
1. throws away too much resolution
Half-resolution demosaic

- Idea 1: treat each block of four pixels as a pixel

Easy to code up in one line of Matlab. But what is wrong with this?
1. throws away too much resolution
2. produces subpixel shifts in color planes!
block
bayer
block
Centered half-resolution

- Average pixels in groups that all have the same “center of gravity”
  avoids major color fringing
block
Naïve full-resolution interpolation

• What if we don’t want to throw away so much sharpness?
dcraw

dcraw
block
centered
naïve full-res
naïve full-res

block
naïve full-res

centered
naïve full-res
Results of simple linear
Results - not perfect
Questions?
The problem

• Imagine a black-on-white corner
• Let’s focus on the green channel for now
The problem

• Imagine a black-on-white corner
The problem

- Imagine a black-on-white corner
The problem

- Imagine a black-on-white corner
Yep, that’s what we saw
Green channel
Edge-based Demosaicking
Idea

• Take into account structure in image
  - Here, 1D edges

• Interpolate along preferred direction
  - In our case, only use 2 neighbors
How do we decide

- Look at the similarity of recorded neighbors
  - Compare \(|\text{up-down}|\) and \(|\text{right-left}|\)
  - Be smart
  - See pset 4

- Called edge-based demosaicking

\[
\begin{array}{cccc}
0 & 0 & 1 & \\
0 & 0 & 1 & \\
0 & 0 & 1 & \\
0 & 0 & 1 & \\
1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 \\
\end{array}
\]
Green channel -- naive
Green channel -- edge-based
Challenge with other channels
Problem

• What do we do with red and blue?
• We could apply the edge-based principle
• But we’re missing more information
• But color transitions might be shifted
Example

- Black on white corner
- Notion of edge-based unclear for pixels in empty rows or columns
Example

• Black on white corner

• Even if we imagine we can do some decent job for each channel
Example

- Black on white corner
- Even if we imagine we can do some decent job for each channel
- The channels don’t line up
  - Because they are not recorded at the same location
Example

- Bad color fringes!
Recall color artifacts
Green-based Demosaicking
Green-based demosaicking

- Green is a better color channel
  - Twice as many pixels
  - Often better SNR
  - We know how to do edge-based green interpolation

- Do the best job you can and get high resolution from green

- Then use green to guide red & blue interpolation
Interpolate difference to green

• Interpolate green
  - using e.g. edge-based

• For recorded red pixels
  - compute R-G

• At empty pixels
  - Interpolate R-G naively
  - Add G

• Same for blue
Measurements
Edge-based green
Red-Green difference

- Zero everywhere!
Red-Green interpolation

- Easy!
Add back green
Same for blue
Fully naive
Edge-based green, naive red blue
Green-based blue and red
Still not 100% perfect

• But will be good enough for pset 4
block
centered
naïve full-res
edge-based
dcraw
dcraw

block
dcraw

dcraw

Cornell CS6640 Fall 2012
centered
naïve full-res
edge-based
dcraw

bayer
dcraw

edge-based
Noise reduction

- Users want noise out of their images
  - shot noise increases as $\sqrt{\text{exposure}}$
  - relative shot noise decreases as $\sqrt{\text{exposure}}$
  - relative readout noise increases prop. to exposure
  - higher ISO settings try to reduce relative readout noise

- Basic approach: average together measurements

- Be clever, spatially, to avoid blurring image structure

- One approach: bilateral filter
  - more on this later

- Camera makes all have their proprietary methods
worth a look:
http://www.dpreview.com/reviews/nikon-d3200/12
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Denoising & Demosaicking

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Links from Frédo


More