Algorithms in a digital camera

Processing digital camera images

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Overview

• Basic algorithms
  – Autofocus
  – Auto exposure
  – Histogram
  – Color balancing

• Advanced algorithms
Camera pipeline

- Auto focus
- Auto exposure
- Auto color balancing

- Aperture size
- Focus
- Exposure duration

- Optic system
  - Lens
  - Color filters
  - Aperture
  - Sensor

- Image analyses
- Interpolation for color reconstruction

- Image memory
- Further computation
Autofocus

• In a small area of the sensor
• Goal: get the highest contrast
Autofocus algorithm

Step 1: Measure the contrast in the focus area

Step 2: A small change is made to the focusing distance

Step 3: Measure the contrast again and calculate if and by how much the contrast improved

Step 4: Use this information to set a new focusing distance

Repeat until a satisfactory focus has been achieved
Auto exposure

Exposure time
Duration, the aperture of a camera is open (shutter speed)

Correct exposure: the entire image is in a good region of the sensor
Auto exposure algorithm

• Algorithm:

Step 1: Take a picture with a pre-determined $EV_{\text{pre}}$

$$EV = \log_2 \left( \frac{F^2}{T} \right) = 2 \log_2 (F) - \log(T)$$

Exposure Value ($EV$) specifies the relationship between aperture size, $F$, and exposure duration, $T$. 
Auto exposure algorithm

Step 2: Convert the RGB values to Brightness $B$

Step 3: Derive a single number $B_{pre}$ from the brightness picture
Step 4: Calculate the optimum exposure $EV_{\text{opt}}$, which should give us a brightness value close to $B_{\text{opt}}$

$$EV_{\text{opt}} = EV_{\text{pre}} + \log 2(B_{\text{pre}}) - \log 2(B_{\text{opt}})$$

$B_{\text{opt}}$: Brightness value from a calibration against a 18% grey card
Histogram

Shows the distribution of the pixel values
Learn to “read” a histogram

Correctly exposed image
underexposed image
overexposed image
Color balancing (e.g. White balancing)

- Humans adept to varying illumination conditions
- Image sensors can't, we have to compute it
Two ways of balancing:
  – Pre-computed sets
  – Guess with an algorithm
Grey world algorithm

Assumes, that the average color of the RGB values are equal (=grey)

\[ R_{avg} = G_{avg} = B_{avg} \]

If not, compute coefficients to make them equal

\[ \tilde{\alpha} = \frac{G_{avg}}{R_{avg}} \quad \tilde{\beta} = \frac{G_{avg}}{B_{avg}} \]

Good results, if picture has many colors
On camera implemented advanced algorithms:

- HDR
- Panorama stitching
- Face detection
- Focus bracketing
- ...
Thank you for listening
Auto-focus

Schematic auto focus system