Projects: examples, now and Friday 3-5pm → office hour every friday

Kinect: 2 units for Loan

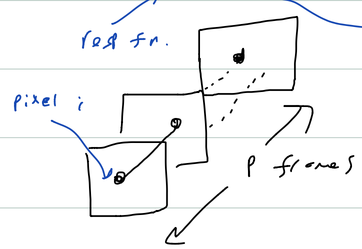
Today: Review HDR LSQ

Friday: Asst # 1 Out.

(Point Grey "3D" Camera maker)

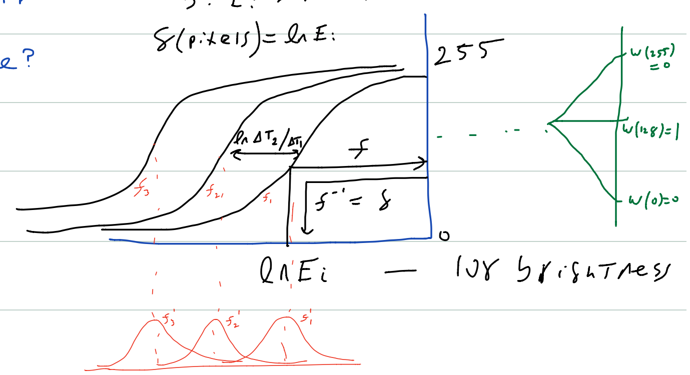
pixel value ↓ $Z_{ij} = f(E_i \Delta T_j) + n_{ij}$ ← noise → amplifier, ADC

(pixel ↓ E_i; exposure time ↓ ΔT_j; resp. fn. → f; sensor noise?)



$f: E_i \to \text{pixels}$

$g(\text{pixels}) = \ln E_i$



$Z_{ij} = f[E_i \Delta T_j]$

$f^{-1}(Z_{ij}) = E_i \Delta T_j$

$\ln f^{-1}(Z_{ij}) = \ln E_i + \ln \Delta T_j$

$g(Z_{ij}) = \ln E_i + \ln \Delta T_j$

$g(Z_{i1}) = \ln E_i + \ln \Delta T_1$ (→ 0)

$g(Z_{i2}) = \ln E_i + \ln \Delta T_2$

g is a lookup table (LUT) maps pixel values $0 \dots 255 \to \ln E_i$

Convention

Let $\Delta T_1 = 1$ $\qquad \Delta T_1 < \Delta T_2 < \dots < \Delta T_p$

System of Equations

$$g(Z_{ij}) = \ln E_i + \ln \Delta T_j$$

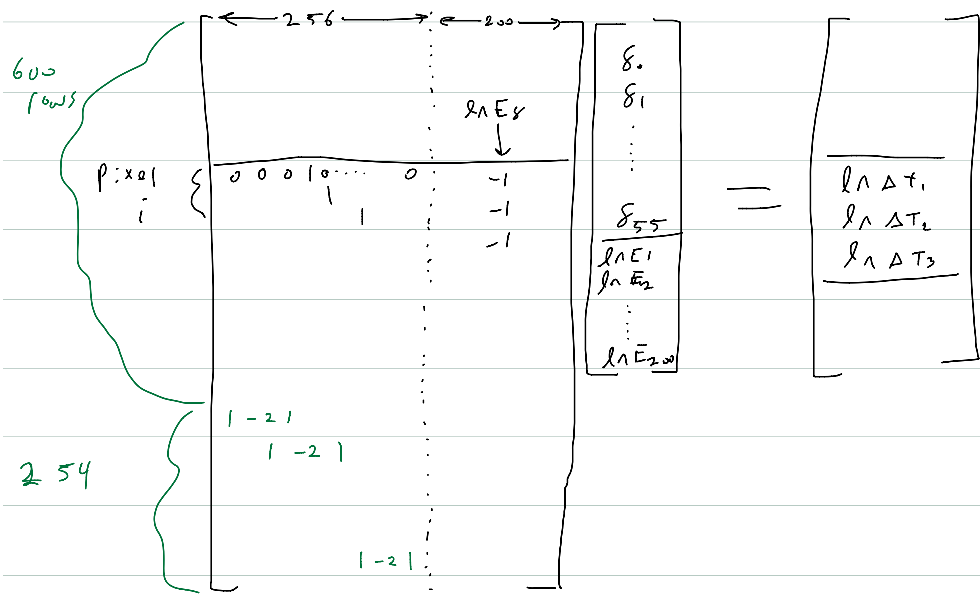
LUT — 256 unknowns

$\ln E_i$: brightness each pixel = 200 → 456 unknowns

$$\sum_{j=1}^{3} \sum_{i=1}^{200} \left[g(Z_{ij}) - \ln E_i = \ln \Delta T_j \right]^2$$

Sum of squared errors

3 Images × 200 Points = 600 equations



Emergency CS370

Least Squares (LSQ)

Let $\varepsilon^2 = \frac{1}{2}\|Ax - b\|^2$ $\qquad \varepsilon^2 = \frac{1}{2}(Ax-b)^T(Ax-b)$

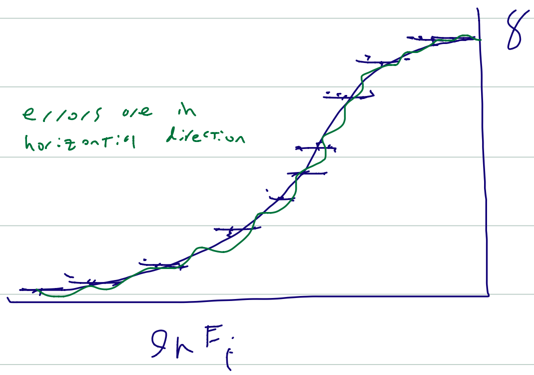
$$\frac{\partial \varepsilon^2}{\partial x} = \boxed{A^T A x - A^T b = 0}$$

normal equations → $\boxed{A^T A x = A^T b}$

$$\hat{x} = \boxed{(A^T A)^{-1} A^T} b$$

→ pseudoinverse

$\boxed{\hat{x} = A \backslash b}$ → Matlab



$\hat{x} = \arg\min_x \|Ax - b\|^2$

$x_1 \geq x_2 \geq \cdots \geq x_{256}$

Quadratic programming

Regularization

$$\epsilon^2 = \sum_{j=1}^{3}\sum_{i=1}^{200}\left(g(z_{ij}) - \ln E_i = \ln \Delta T_j\right)^2 + \lambda \sum_{i=1}^{256}\left(g''_i\right)^2$$

λ → smoothness weight penalty

$\sum_{i=1}^{256}(g''_i)^2$ → smoothing term

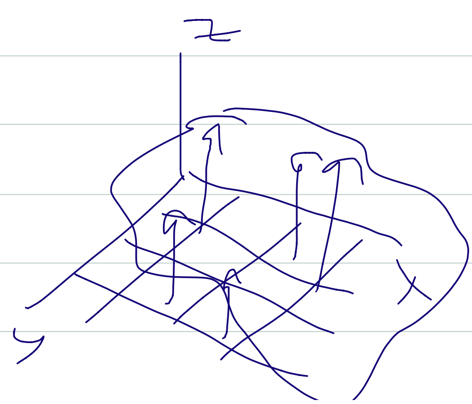
Finite Diff operators T & V Appendix

$$g'_i = \frac{g_{i+1} - g_{i-1}}{2h} + O(h^2)$$

← interval h

$$g''_i = \frac{g_{i+1} - 2g_i + g_{i-1}}{h} + O(h)$$

High maps (distance)



best fit surface f

$$\varepsilon^2(\vec{f}_i, \vec{y}_i) = \sum_{i \in M} (y_i - f_i)^2 + \lambda \sum_{i \in A} (f''_i)^2$$

- $\vec{y}_i$: measured (sparse)
- $\sum_{i \in M} (y_i - f_i)^2$: measured, data fit
- $\lambda \sum_{i \in A} (f''_i)^2$: smoothness terms on surface

How to display HDR image "Tone mapping"

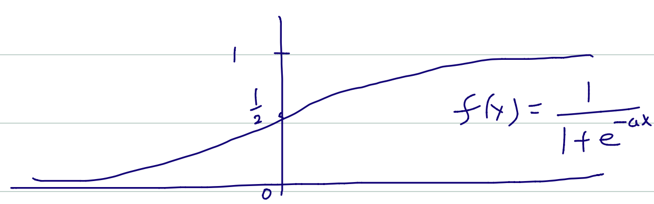
Step 1: Finding E_i

$$\hat{E}_i = \frac{\left[w(z_{i1})\left(g(z_{i1}) - \ln \Delta T_1\right) + w(z_{i2})\left(g(z_{i2}) - \ln \Delta T_2\right) + w(z_{i3})\left(g(z_{i3}) - \ln \Delta T_3\right) \right]}{w(z_{11}) + w(z_{12}) + w(z_{13})}$$

$\hat{E}_i$: estimate of a new pixel

Step 2: Tone Mapping

1) Choose (eg middle) frames as reference
2) Remap new curve



3) Psychophysical considerations
   → "Exposure fusion" + HDR