Focal Track

Depth and Confidence with Oscillating Lens Deformation

Harvard SEAS

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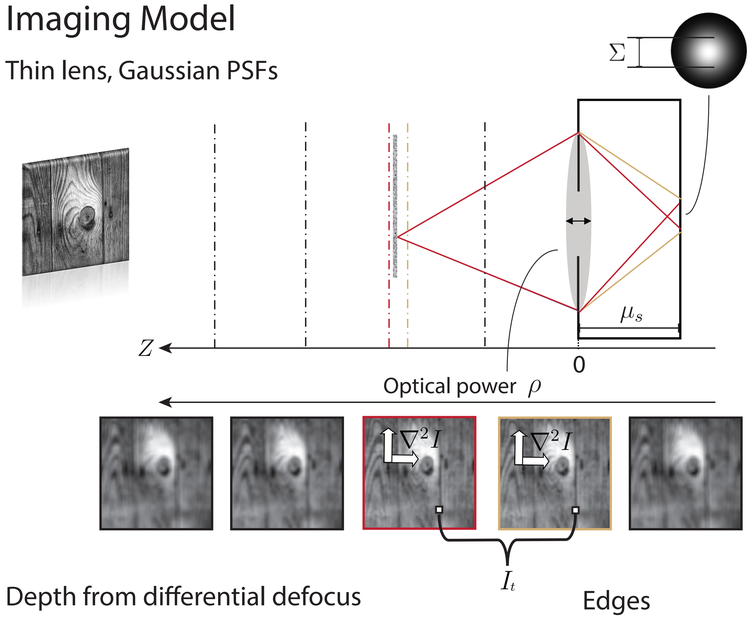
Motivation

Small, passive, low power depth sensors

Imaging Model

Thin lens, Gaussian PSFs



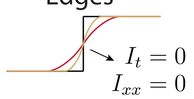
Depth from differential defocus

$$I_t = f(Z)\nabla^2 I$$

$$Z = \frac{\partial_x^j \partial_y^k V}{\partial_x^j \partial_y^k W} \qquad V = \left(\Sigma^2 \mu_s^2 \dot{\rho}\right) \nabla^2 I = \alpha \nabla^2 I$$

$$W = \left(\Sigma^2 \mu_s \dot{\rho}\right) \left(\mu_s \rho - 1\right) \nabla^2 I - I_t = \beta \nabla^2 I - I_t$$

Edges



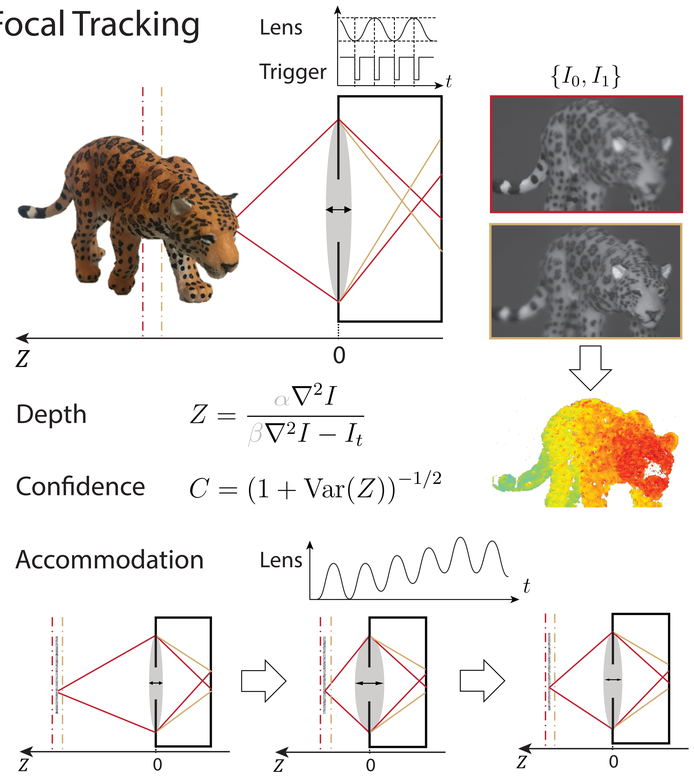
Confidence

Gaussian noise model: $I = I^* + \epsilon$

Confidence: $C = (1 + \mathrm{Var}(Z))^{-1/2}$

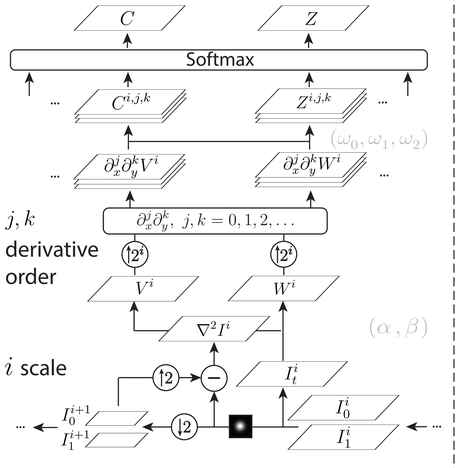
$$\approx \left(\frac{\omega_0}{W^2} + \frac{V^2 \omega_1}{W^4} + \frac{V \omega_2}{W^3} + 1 \right)^{-1/2}$$

Focal Tracking



End-to-end Calibration

Computational tree



Loss functions

$L(Z_{true}, Z, C)$

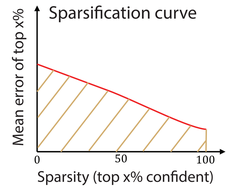
1. *p*-norm loss

$(\mathrm{mean}(|Z - Z_{true}|)^p)^{1/p}$

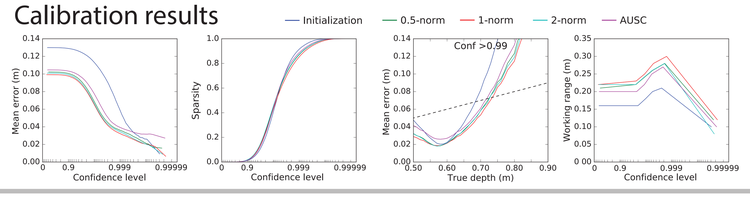
2. Area under sparsification curve

$\mathrm{mean}\ (\lambda \cdot \mathrm{sort}\ (|Z - Z_{true}|, C))$

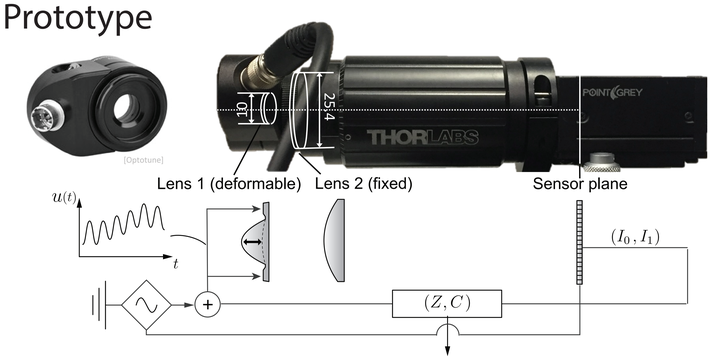
$\lambda = \left[\frac{1}{N}, \ldots, \frac{1}{N} + \frac{1}{N-1} \ldots + 1\right]$



Calibration results

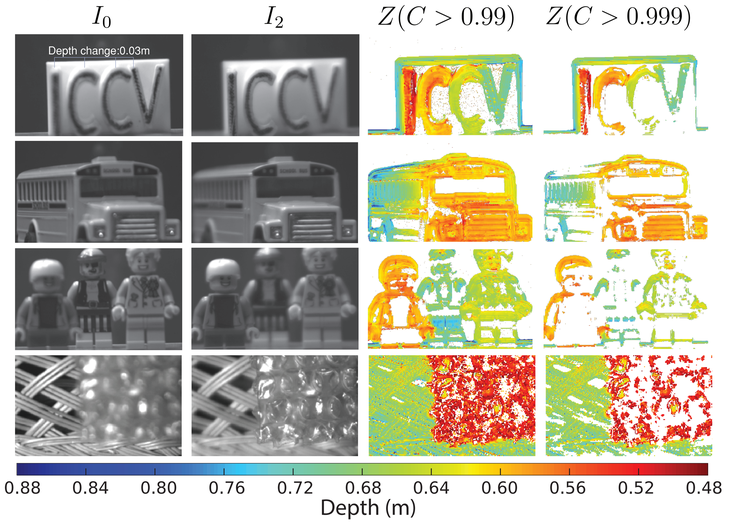


Prototype

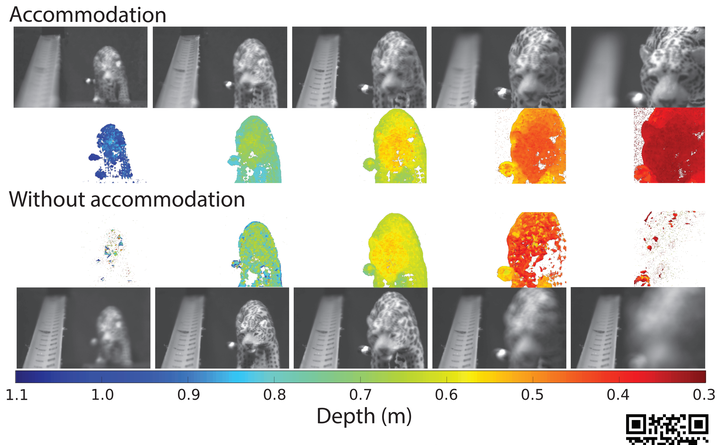


Results (100FPS, 300x480)

Depth maps for different confidence levels



Benefits of accommodation (>75 cm range, < 4cm error)



Project page: *vision.seas.harvard.edu/focaltrack*