ICVSS 2014
Sicily ~ 13-19 July
International Computer Vision Summer School

Exploiting Shading Cues in Kinect IR images for Geometry Refinement

Published in CVPR 2014

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Motivation

Using IR Instead of color

Geometry from Low cost depth sensor

Images for geometry refinement

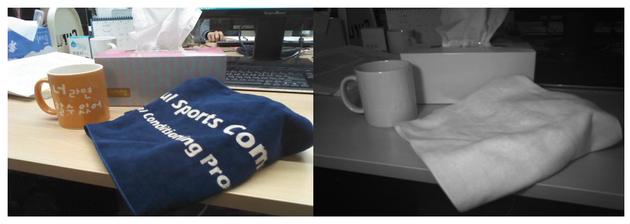
High-quality 3D geometry

Advantages of IR Image

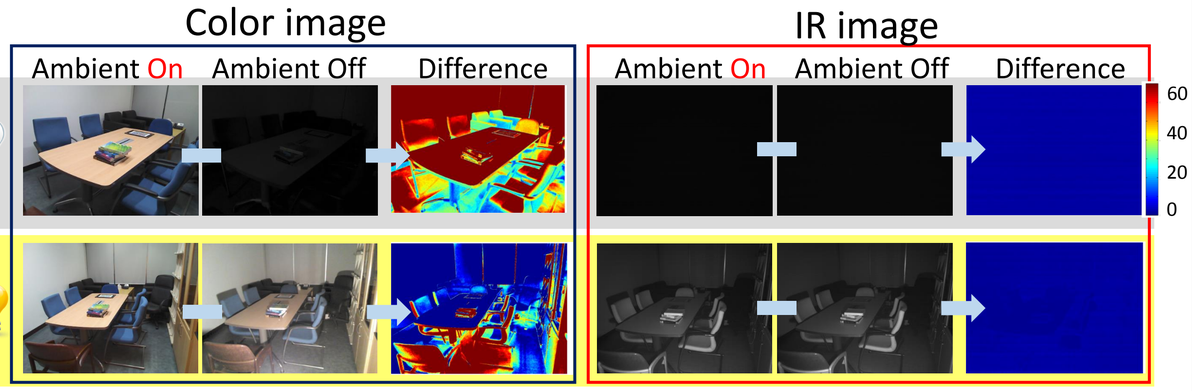
① Simple Setup

No need for color camera

② Less Albedo Variance

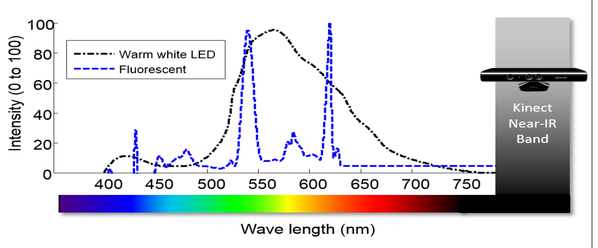


③ IR Invariability under Indoor Lightings



- Kinect IR camera filters out most undesired ambient light that makes our system robust to indoor illumination.
- Our method works well in both dark room and natural lighting environment.

Kinect Near-IR Band



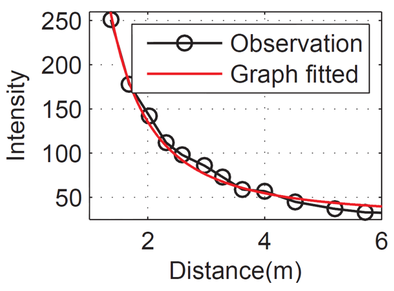
Our IR Light Model

$$I(u) = \frac{c\rho}{d^2}(n \cdot l) + I_{Ambient}$$

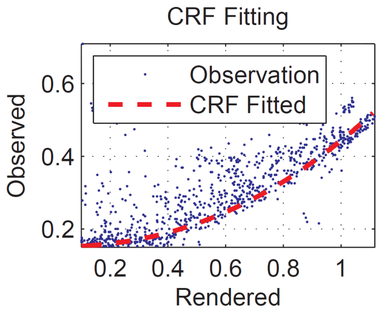
The beauty of IR

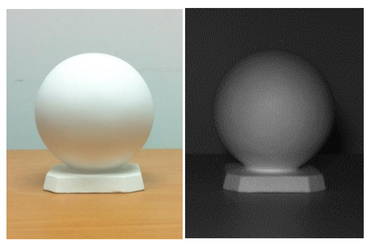
$I(u)$: pixel intensity,
ρ : albedo of surface, n : surface normal,
l : lighting direction, c is the global brightness
d : the distance between surface point and center of light source

Inverse Square Law



CRF Fitting





Color IR

- To radiometrically calibrate the IR shading images, we use intensity observations of a known geometry and determine the gamma function.

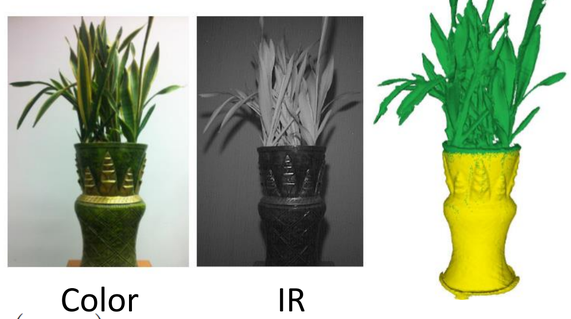
Multiple Albedo handling

Single albedo

$$c\rho = \frac{1}{Z}\sum_{i=1}^{N}\sum_{\substack{m=1,\\ \mathbf{u}_{i,m}\in V_i}}^{M}\frac{d_{i,m}^2}{\mathbf{n}_{i,m}\cdot\mathbf{l}_{i,m}}I_m(\mathbf{u}_{i,m})$$

Multiple albedo

$$c\rho_i = \frac{1}{Z_i}\sum_{\mathbf{x}_j\in N(\mathbf{x}_i)}\sum_{\substack{m=1,\\ \mathbf{u}_{i,m}\in V_i}}^{M}\frac{d_{j,m}^2}{\mathbf{n}_{j,m}\cdot\mathbf{l}_{j,m}}I_m(\mathbf{u}_{j,m})$$

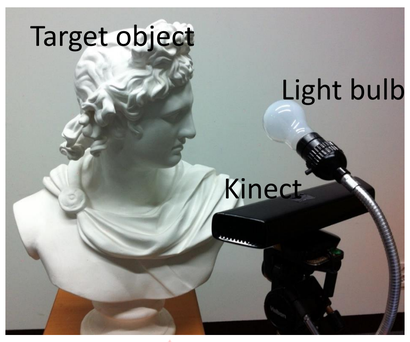


Color IR

Grouped IR albedo

K-means clustering for albedo grouping. 4-dimensional feature $[x\ y\ z\ c\rho]$ is used.

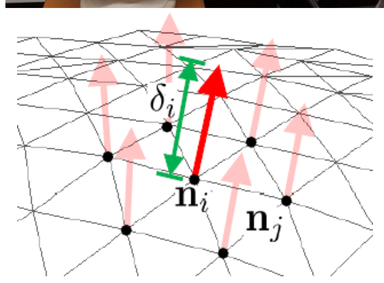
Capturing Setup & Mesh Optimization



input shading images

Projected mesh vertices

Depth map derived from a Kinect fusion mesh



Update $\boldsymbol{x_i}$ along with the normal direction $\boldsymbol{n_i}$

$$\mathbf{x}_i^t = \mathbf{x}_i^{t-1} + \delta_{i,t}\mathbf{n}_i^{t-1}$$

Minimizing the energy function below.

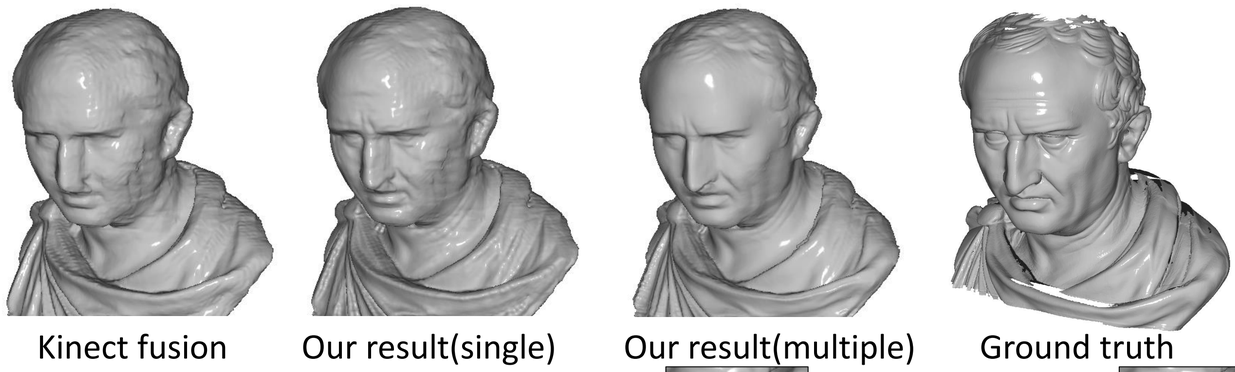
$$\arg\min_{\delta} E_p(\boldsymbol{\delta}) + E_s(\boldsymbol{\delta}),$$

$$E_p(\boldsymbol{\delta}) = \sum_{i=1}^{p}\sum_{k\in V_i} w_{i,k}\left(i_{i,k} - c\rho\frac{\mathbf{n}_{i,k}(\delta_{i,k})\cdot\mathbf{l}_{i,k}}{d_{i,k}^2}\right)^2$$

$$E_s(\boldsymbol{\delta}) = \sum_{i=1}^{p}\sum_{j\in N_i}\lambda_1(\delta_i-\delta_j)^2 + \sum_{i=1}^{p}\lambda_2(\delta_i)^2,$$

i is shading intensity, δ is displacement of vertices, $w_{i,k} = \boldsymbol{n_{i,k}}\cdot\boldsymbol{l_{i,k}}$
λ_1 and λ_1 are the weights for local smoothness and regularizer term respectively.

Experimental Results



Kinect fusion | Our result(single) | Our result(multiple) | Ground truth