Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras

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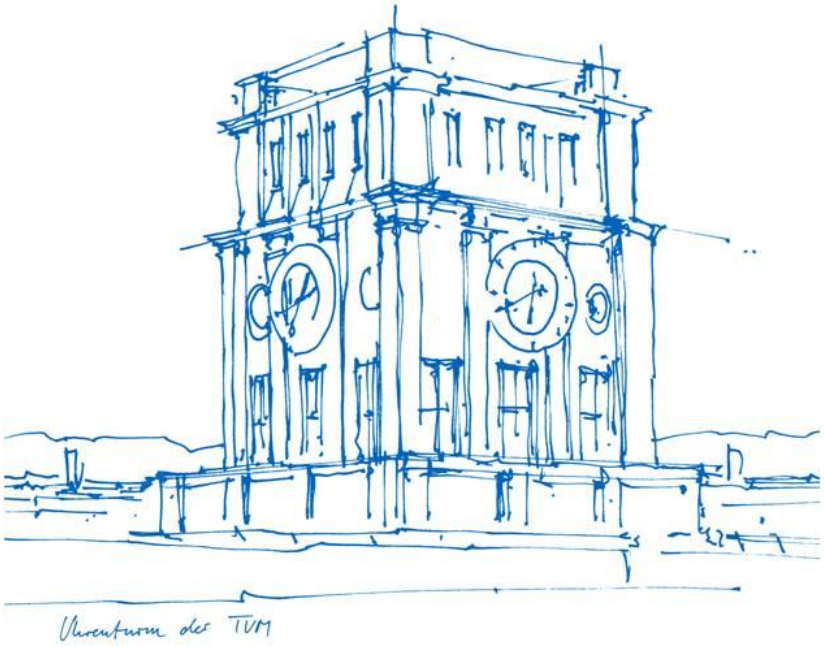
ACM Transactions on Graphics 33(4), 2014

An Overview of Methods for Accurate
Geometry Reconstruction Seminar
Filip Bojadzievski



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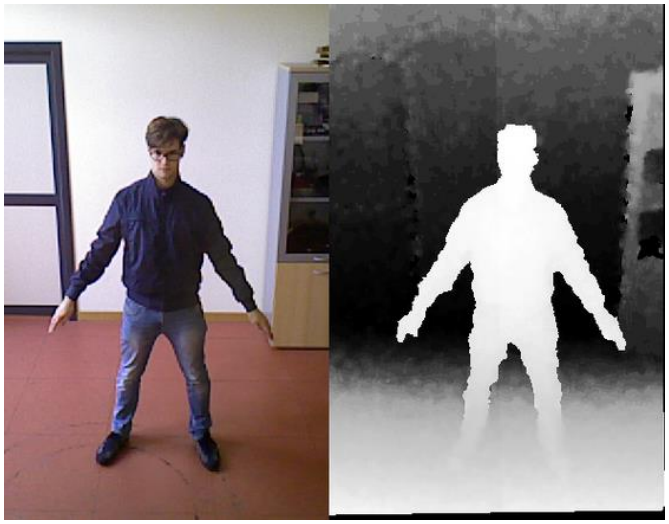
Outline

1. Sensors and Input Data
2. Preprocessing
3. Objective Function
4. Results
5. Summary

Sensors and Input Data



Retrival of Human Subjects from Depth Sensor Data [Link].

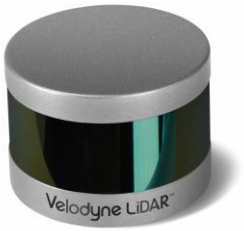
RGB-D

Asus Xtion Pro Live
Source: [Link]

ToF

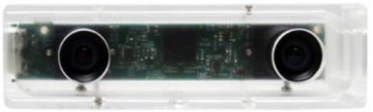
Oppo R17 Pro
Source: [Link]

LiDAR



Velodyne LiDAR
Source: [Link]

Stereo Cameras



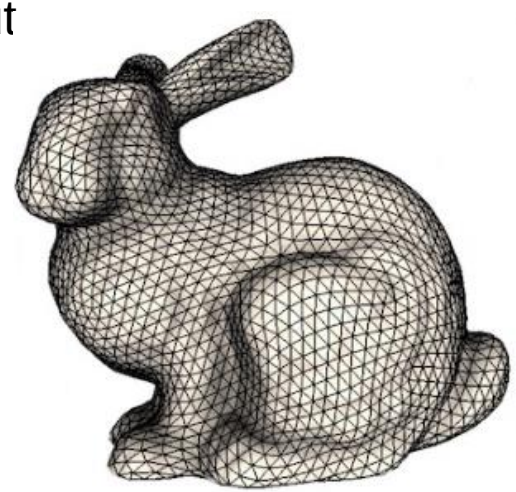
Tara Stereo Camera
Source:[Link]

Sensors and Input Data

Source: Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras. *ACM Transactions on Graphics 33(4), 2014*
[Link].

Preprocessing

1. Geometric Reconstruction using Depth Input



Source: http://www.meshlab.net/

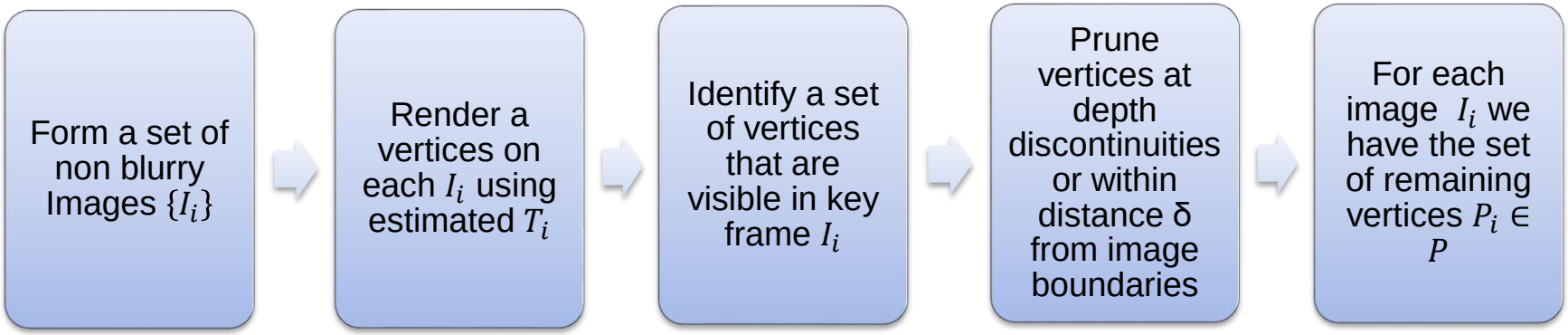
- In other words, the goal is to generate a 3D mesh

- Accomplished with KinnectFusion

KinnectFusion: Real Time Dense Surface Mapping and Tracking [Link].

Preprocessing

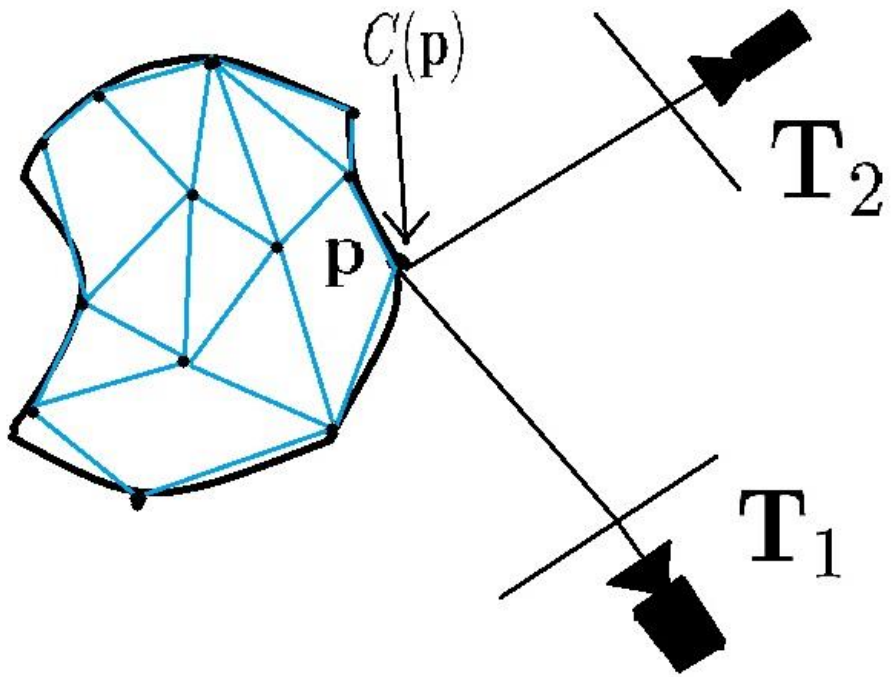
1. Geometric reconstruction using Depth input only
2. Key frame selection and vertex pruning



Objective Function

Can we do colour reconstruction using what we already have?

- We have RGB Images and estimated camera poses T_i
- We have a set of vertices P_i visible in each image T_i



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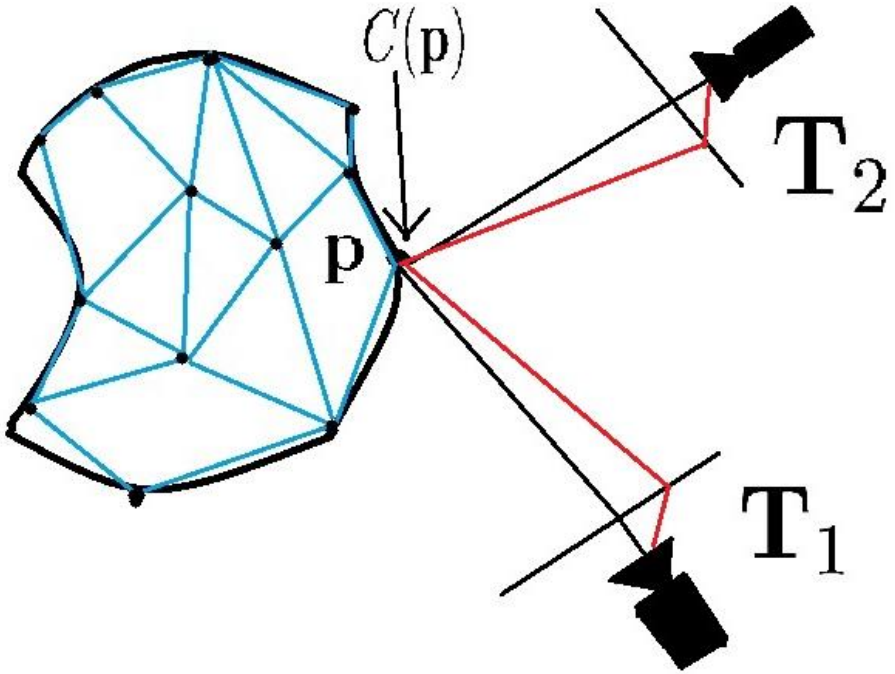
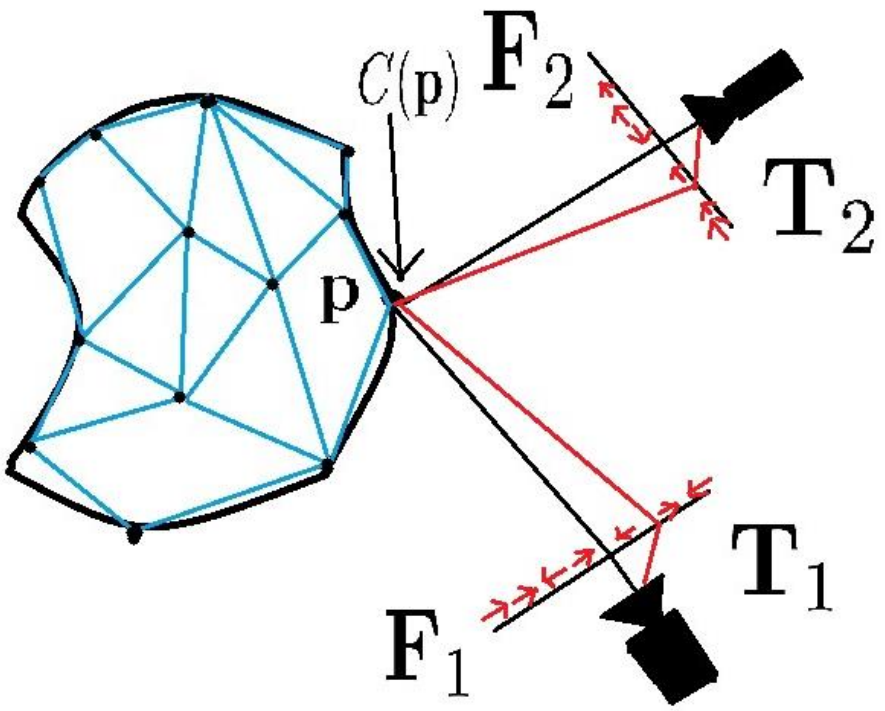


Objective Function

Can we do colour reconstruction using what we already have?

- We have RGB Images and estimated camera poses T_i
- We have a set of vertices P_i visible in each image T_i
- Our T_is correspond to depth cameras so they need to be optimized
- We also optimize non rigid corrections F_i



Objective Function

Minimize:

$$E(C,T) = \sum_i \sum_{p \in P_i} (C(\boldsymbol{p}) - \Gamma_i(\boldsymbol{p}, \boldsymbol{T}_i))^2$$

- $C(\boldsymbol{p})$ is proxy variable for color of point $\mathbf{p}$
- $\Gamma_i(\boldsymbol{p}, \boldsymbol{T}_i) = \Gamma_i(\boldsymbol{u}(\boldsymbol{g}(\boldsymbol{p}, \boldsymbol{T}_i))$

Objective Function

$$E(C,T) = \sum_i \sum_{p \in P_i} (C(\boldsymbol{p}) - \Gamma_i(\boldsymbol{p}, \boldsymbol{T}_i))^2 = \sum_i \sum_{p \in P_i} r_{i,p}^2$$

- Use Gauss-Newton
- $x^0 = [\boldsymbol{C}^0, \boldsymbol{T}^0]$
- Solve: $J_r^T J_r \Delta \mathrm{x} = -J_r^T r$
- Update: $x^{k+1} = x^k + \Delta x$

Objective Function

- Idea is to alternate between optimizing C and optimizing T.

- When T is fixed, we are solving linear least-squares problem:

$$C(\boldsymbol{p}) = \frac{1}{n_p} \sum_{I_i \epsilon I_p} \Gamma_i(\boldsymbol{p}, \boldsymbol{T}_i)$$

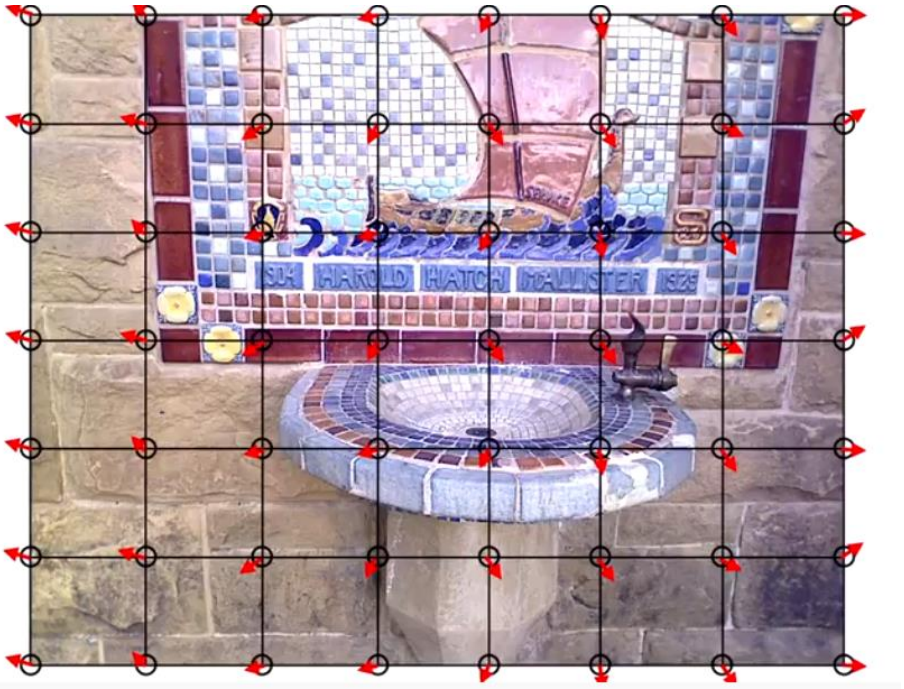
- When C is fixed the objective decomposes into independent objectives for each T_i

$$E_i(\boldsymbol{T}) = \sum_{\boldsymbol{p} \epsilon P_i} r_{i,p}^2$$

- Reduces to n linear systems with 6 variables

Objective Function

- We introduce a deformation function $\boldsymbol{F_i}$ over the image plane I_i
- The parameters of $\boldsymbol{F_i}$ (lattice vectors) are optimized to rectify complex distortions and imprecise geometry.
- $\boldsymbol{F}_i(\boldsymbol{u}) = \boldsymbol{u} + \sum_{\boldsymbol{i}} \theta_i(\boldsymbol{u}) \boldsymbol{f_{i,l}}$
- $\Gamma_i(\boldsymbol{p}, \boldsymbol{T}_i, \boldsymbol{F}_i) = \Gamma_i(\boldsymbol{F}_i(\boldsymbol{u}(\boldsymbol{g}(\boldsymbol{p}, \boldsymbol{T}_i))))$



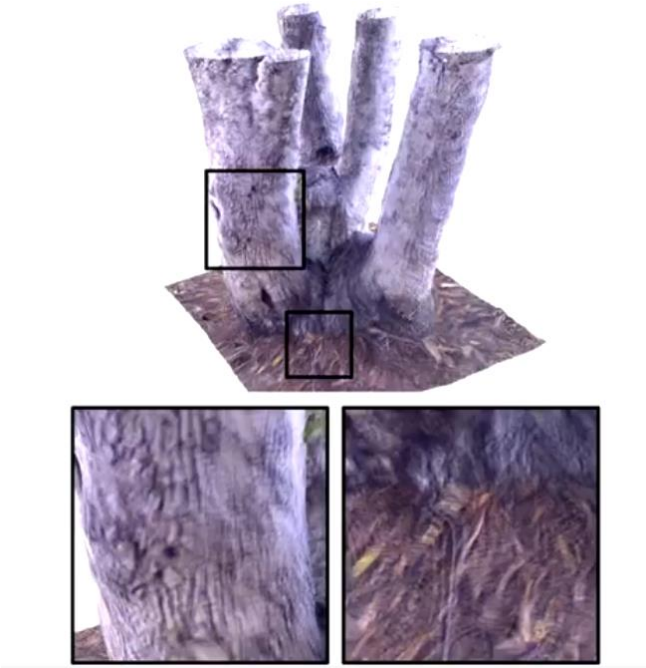
Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras [Link]

Main objective: $E(C, T, F) = \sum_i \sum_{p \in P_i} (C(\boldsymbol{p}) - \Gamma_i(\boldsymbol{p}, \boldsymbol{T}_i, \boldsymbol{F}_i))^2 + \lambda E_r(\boldsymbol{F})$

Results

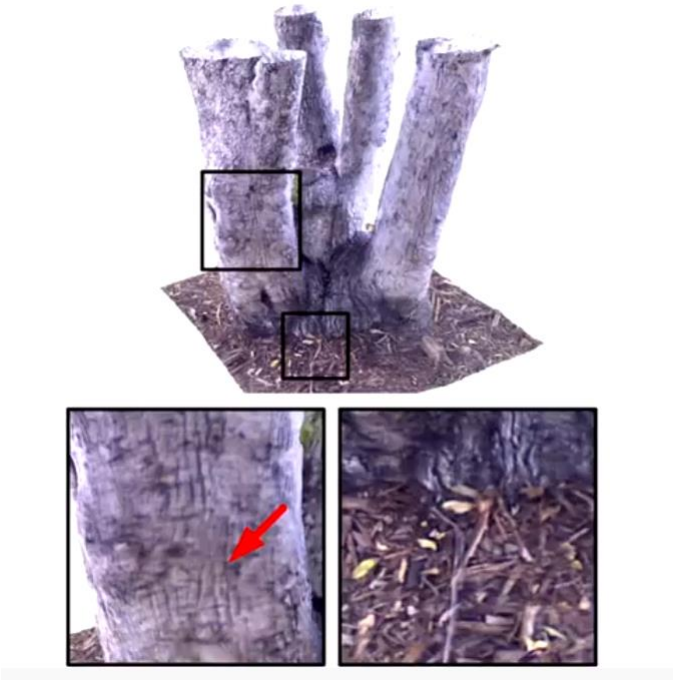
Source: Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras. *ACM Transactions on Graphics 33(4), 2014*
[Link].

Results



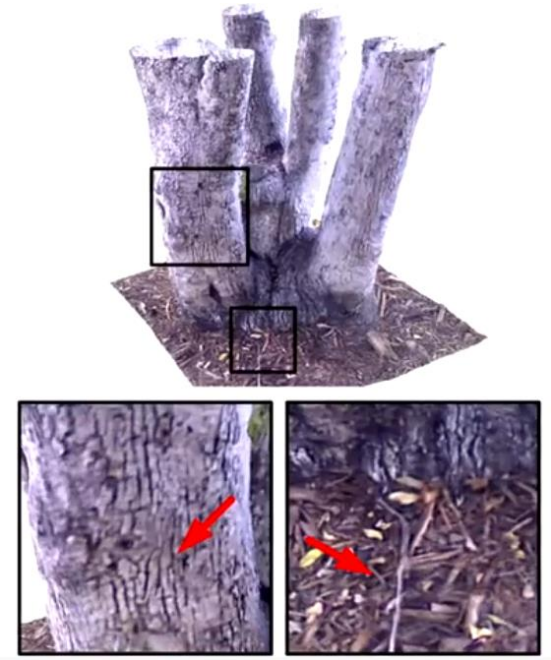
Without Optimization. Source: Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras. *ACM Transactions on Graphics 33(4), 2014* [Link].

Results



Camera pose only. Source: Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras. *ACM Transactions on Graphics 33(4), 2014* [Link].

Results



Complete Objective. Source: Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras. *ACM Transactions on Graphics 33(4), 2014* [Link].

Results

Source: Color Map Optimization for 3D Reconstruction with Consumer Depth Cameras. *ACM Transactions on Graphics 33(4), 2014* [Link].

Personal Comments

- Current flagship phones with depth technologies can already create colourful 3D models (Samsung S10).
- 3D print the reconstructed models of objects or people
- Gaming industry
- Integration with AR

Summary

- Input data are RGB and Depth images
- Build geometric model with KinectFusion
- For each image form a set of visible vertices
- Goal is to find a color of each vertex
- Alternating optimization
- Final color is weighted average

Thank you!