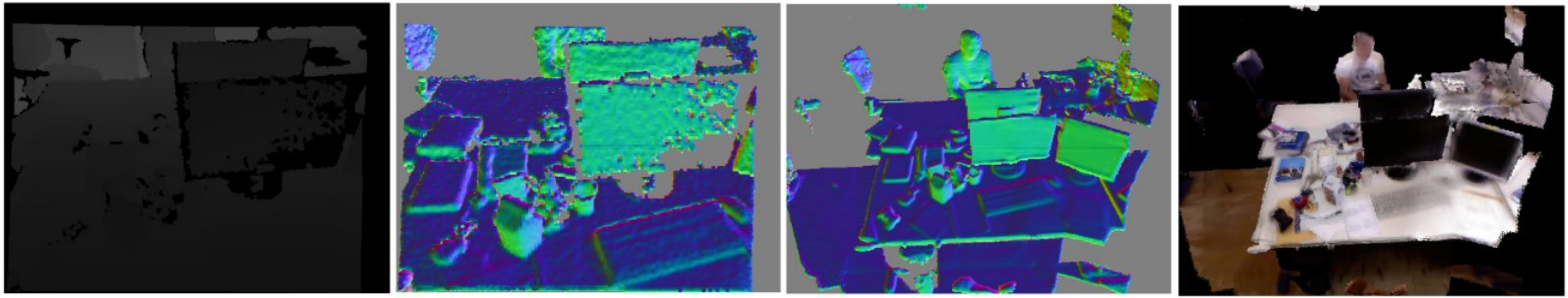
KinectFusion

Marc Benedí San Millán Kerem Yildirir Yigit Aras Tunali Poyraz Kivanc Karacam

“Team 18”



KinectFusion: Real-Time Dense Surface Mapping and Tracking*

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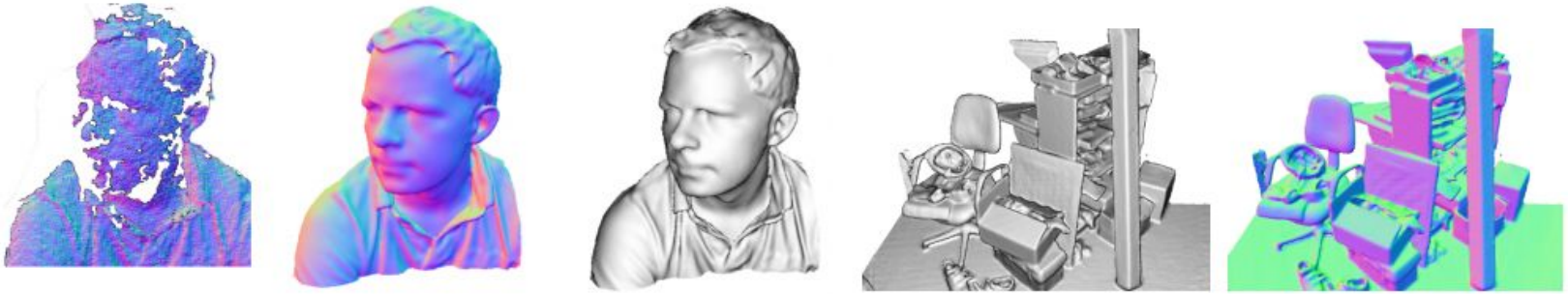
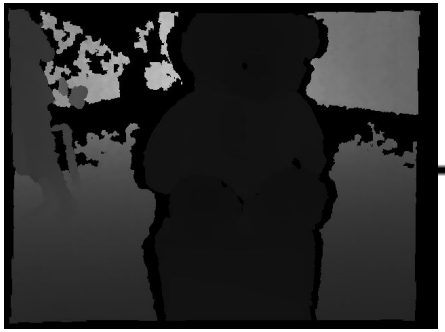
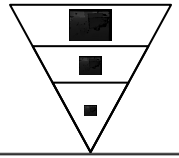
Steve Hodges
Microsoft Research

Andrew Fitzgibbon
Microsoft Research



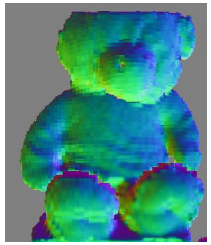


Remove invalid mesurements



Build pyramid

- Compute normal map
- Construct vertex map
- Apply bilateral filter

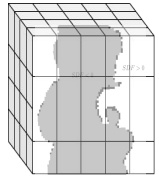


ICP

k+1

Surface prediction

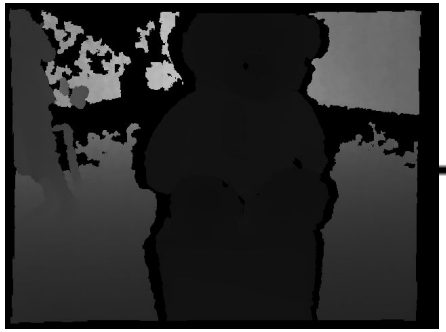
Update reconstruction

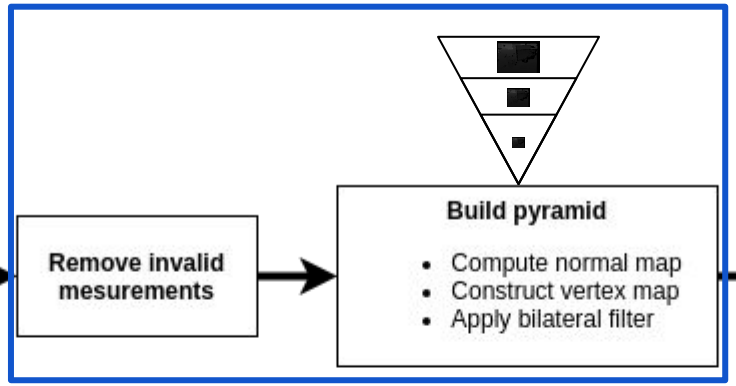


Method | Preprocessing

- Removing edge points and minfs
- Bilateral for smoothing
- Pyramids
- Building point map and normal map

Method | Preprocessing





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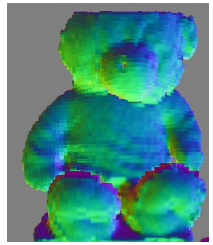
Build pyramid

- Compute normal map
- Construct vertex map
- Apply bilateral filter

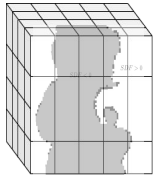


ICP

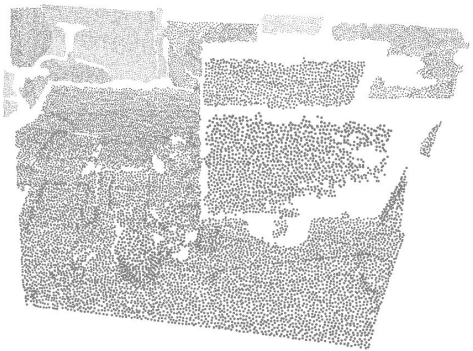
k+1

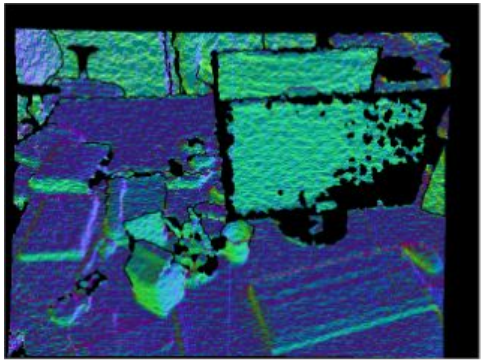
Surface prediction

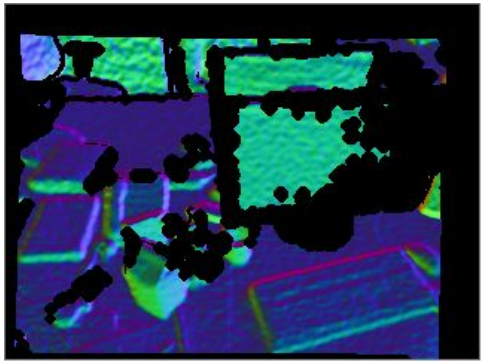
Update reconstruction



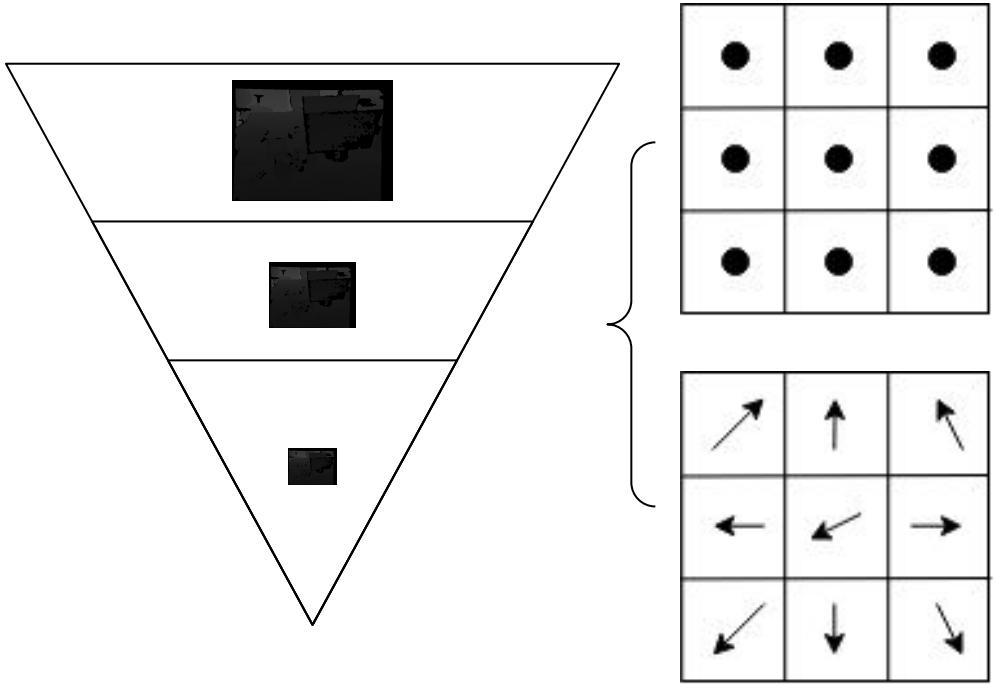
Method | Preprocessing







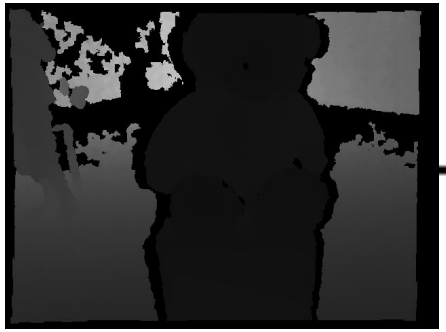
Method | Preprocessing



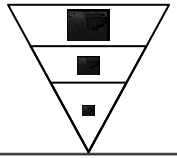
Method | Pose estimation

- Given the previous frame pose
- Given previous surface prediction in global
- Find point-to-plane correspondences
  - Projection thing
- Perform linearized ICP
  - Build matrix
  - Solve it
  - Update step
- FRAME TO FRAME

Method | Pose estimation



Remove invalid mesurements



Build pyramid

- Compute normal map
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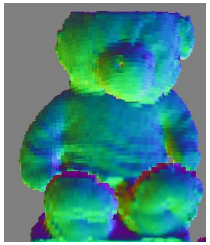
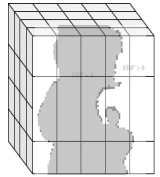


ICP

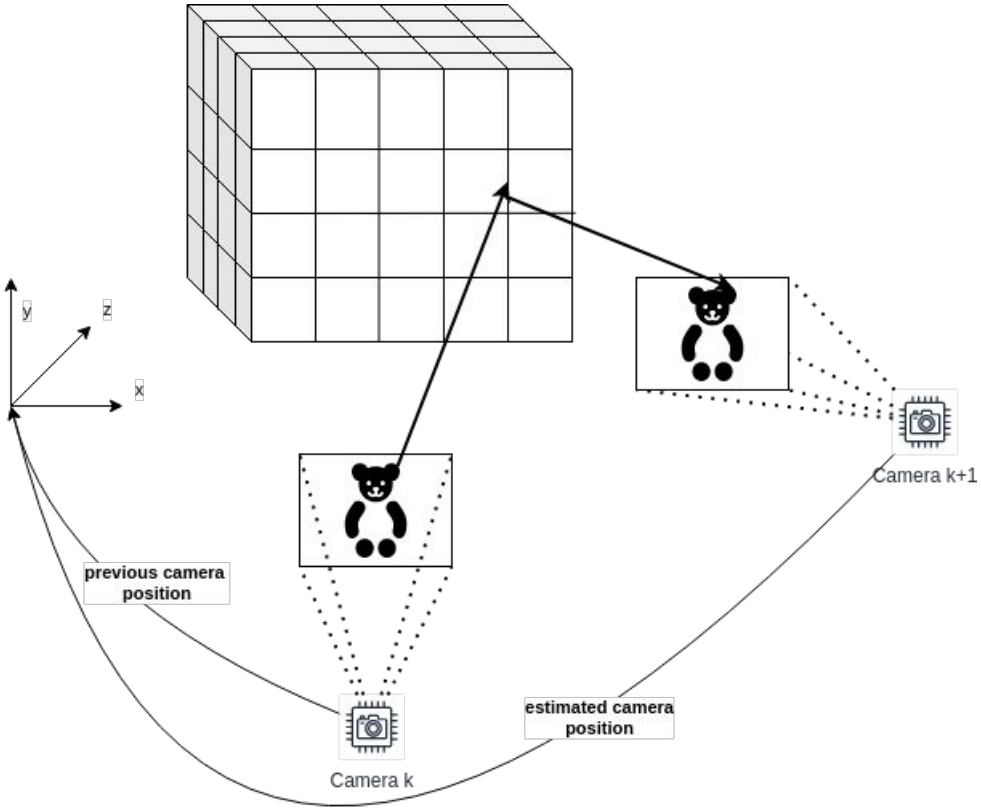
k+1

Surface prediction

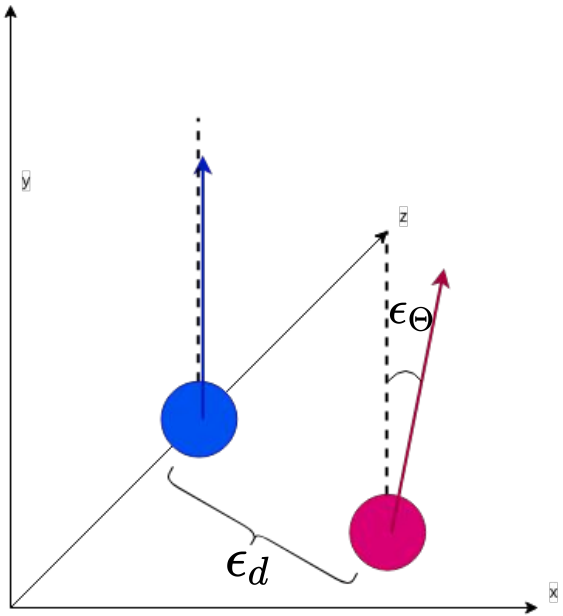
Update reconstruction



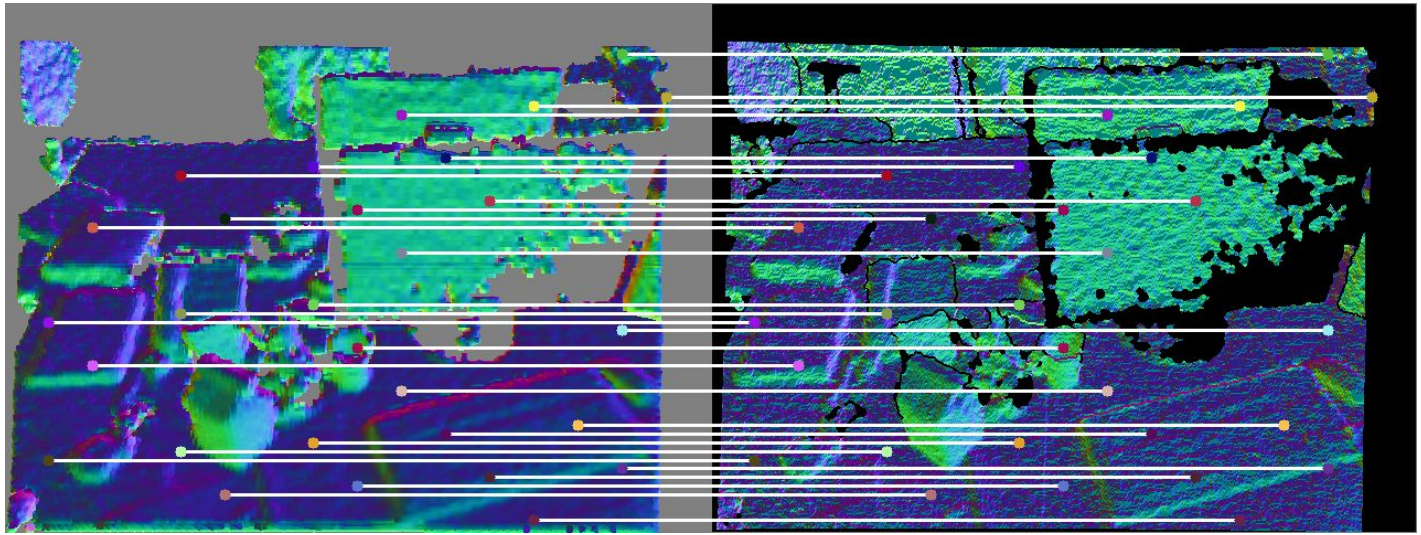
Method | Pose estimation



Method | Pose estimation



Method | Pose estimation

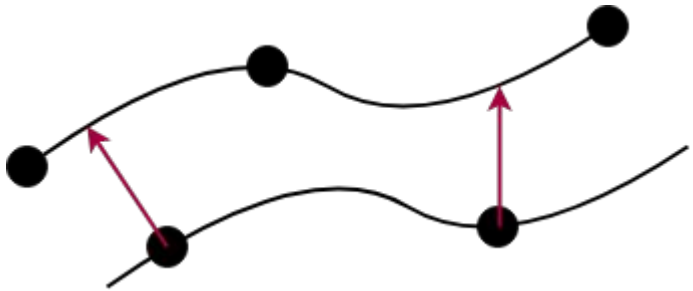


$$E \approx \Sigma((\mathbf{p}_i - \mathbf{q}_i) \cdot \mathbf{n}_i + \mathbf{r} \cdot (\mathbf{p}_i \times \mathbf{n}_i) + \mathbf{t} \cdot \mathbf{n}_i)^2$$

Method | Pose estimation

$$\mathbf{A} = \begin{pmatrix} \leftarrow & \mathbf{p}_1 \times \mathbf{n}_1 & \rightarrow & \leftarrow & \mathbf{n}_1 & \rightarrow \\ \leftarrow & \mathbf{p}_2 \times \mathbf{n}_2 & \rightarrow & \leftarrow & \mathbf{n}_2 & \rightarrow \\ & \vdots & & & \vdots & \end{pmatrix} \quad x = \begin{pmatrix} r_x \\ r_y \\ r_z \\ t_x \\ t_y \\ t_z \end{pmatrix}$$

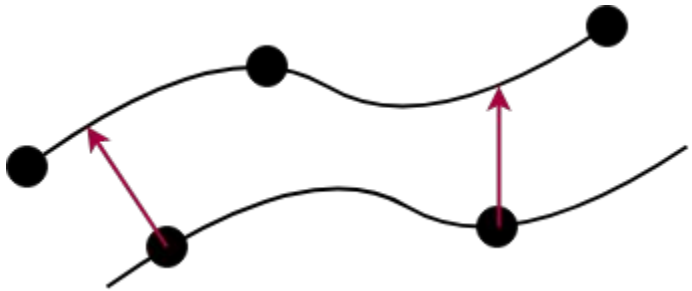
$$b = \begin{pmatrix} -(\mathbf{p}_1 - \mathbf{q}_1) \cdot \mathbf{n}_1 \\ -(\mathbf{p}_2 - \mathbf{q}_2) \cdot \mathbf{n}_2 \\ \vdots \end{pmatrix}$$



$$A^T A x = A^T b$$

$$E := \sum_i ((R\mathbf{p}_i + t - \mathbf{q}_i) \cdot \mathbf{n}_i)^2$$

Method | Pose estimation



$$\mathbf{E}\left(\mathrm{T}_{g,k}\right) = \sum_{\substack{\mathbf{u}\in\mathscr{U} \\ \Omega_k(\mathbf{u})\neq \text{null}}} \left\| \left(\mathrm{T}_{g,k}\dot{\mathbf{V}}_k(\mathbf{u}) - \hat{\mathbf{V}}^g_{k-1}(\hat{\mathbf{u}}) \right)^\top \hat{\mathbf{N}}^g_{k-1}(\hat{\mathbf{u}}) \right\|_2$$

$$E = \hat{\mathbf{N}}^g_{k-1}(\hat{\mathbf{u}})^\top \left(\mathbf{G}(\mathbf{u})\mathbf{x} + \widetilde{\mathbf{V}}^g_k(\mathbf{u}) - \hat{\mathbf{V}}^g_{k-1}(\hat{\mathbf{u}}) \right) \qquad \mathbf{G}(\mathbf{u}) = \left[\left[\tilde{\mathbf{V}}^g_k(\mathbf{u}) \right]_\times \mid \mathbf{I}_{3\times 3} \right]$$

Method | Pose estimation

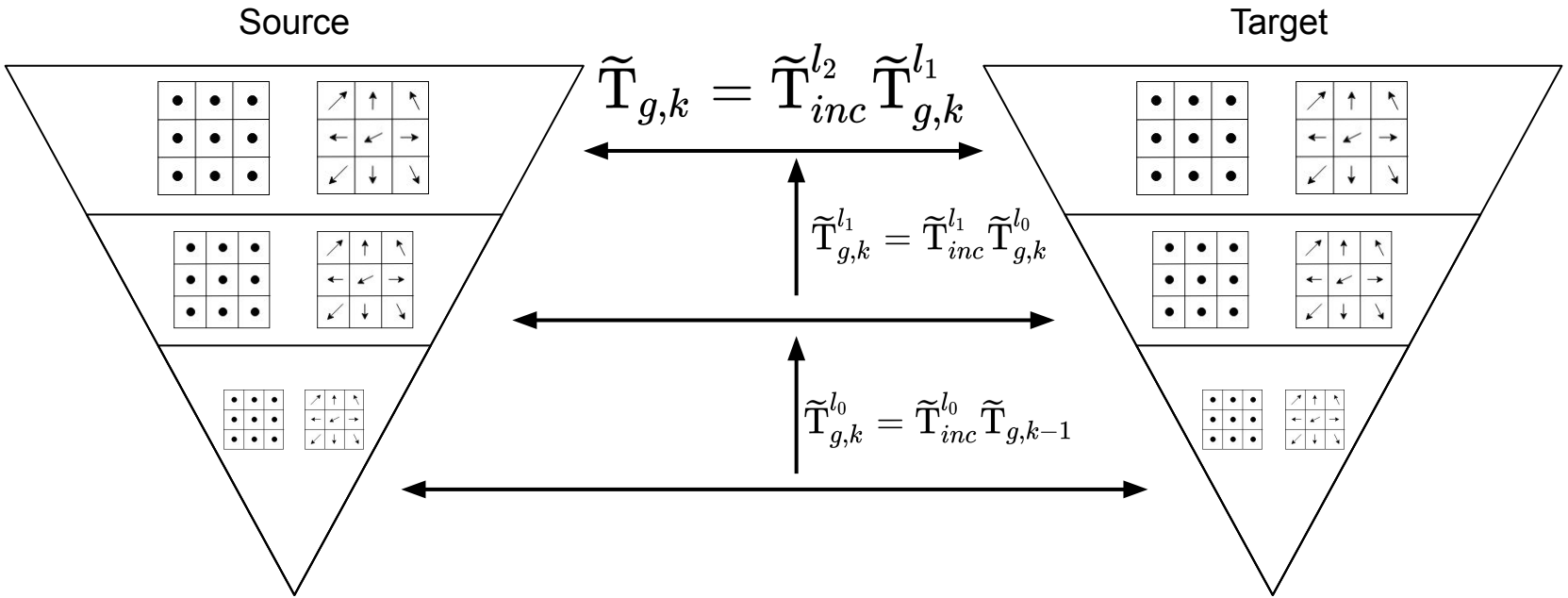
$$\mathbf{A} = \begin{pmatrix} \leftarrow & \tilde{\mathbf{V}}_k^g(\mathbf{u_1}) \times \hat{\mathbf{N}}_{k-1}^g(\hat{\mathbf{u_1}}) & \rightarrow & \leftarrow & \hat{\mathbf{N}}_{k-1}^g(\hat{\mathbf{u_1}}) & \rightarrow \\ \leftarrow & \tilde{\mathbf{V}}_k^g(\mathbf{u_2}) \times \hat{\mathbf{N}}_{k-1}^g(\hat{\mathbf{u_2}}) & \rightarrow & \leftarrow & \hat{\mathbf{N}}_{k-1}^g(\hat{\mathbf{u_2}}) & \rightarrow \\ & \vdots & & & \vdots & \end{pmatrix} \quad x = \begin{pmatrix} \alpha \\ \beta \\ \gamma \\ t_x \\ t_y \\ t_z \end{pmatrix} \quad b = \begin{pmatrix} -\left(\tilde{\mathbf{V}}_k^g(\mathbf{u_1}) - \hat{\mathbf{V}}_{k-1}^g(\hat{\mathbf{u_1}})\right) \cdot \hat{\mathbf{N}}_{k-1}^g(\hat{\mathbf{u_1}}) \\ -\left(\tilde{\mathbf{V}}_k^g(\mathbf{u_2}) - \hat{\mathbf{V}}_{k-1}^g(\hat{\mathbf{u_2}})\right) \cdot \hat{\mathbf{N}}_{k-1}^g(\hat{\mathbf{u_2}}) \\ \vdots \end{pmatrix}$$

$$\widetilde{\mathrm{T}}_{\text{inc}} = \left[\, \widetilde{\mathrm{R}} \mid \tilde{\mathbf{t}} \,\right] = \begin{bmatrix} 1 & \alpha & -\gamma & t_x \\ -\alpha & 1 & \beta & t_y \\ \gamma & -\beta & 1 & t_z \end{bmatrix}$$

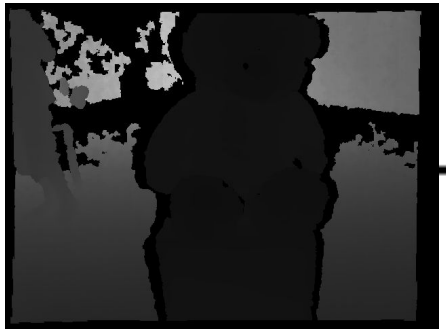
$$\mathbf{min}_{\mathbf{x} \in \mathbb{R}^6} \sum_{\Omega_k} \sum_{\mathbf{u} \neq \text{ null}} \|E\|_2^2$$

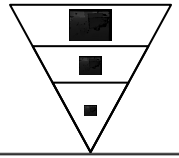
$$A^T A x = A^T b$$

Method | Pose estimation



Method | Update reconstruction





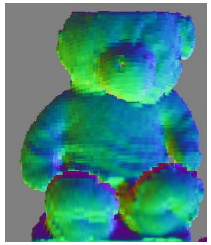
Remove invalid mesurements

Build pyramid

- Compute normal map
- Construct vertex map
- Apply bilateral filter

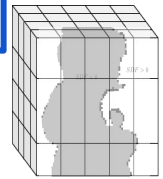
ICP

k+1

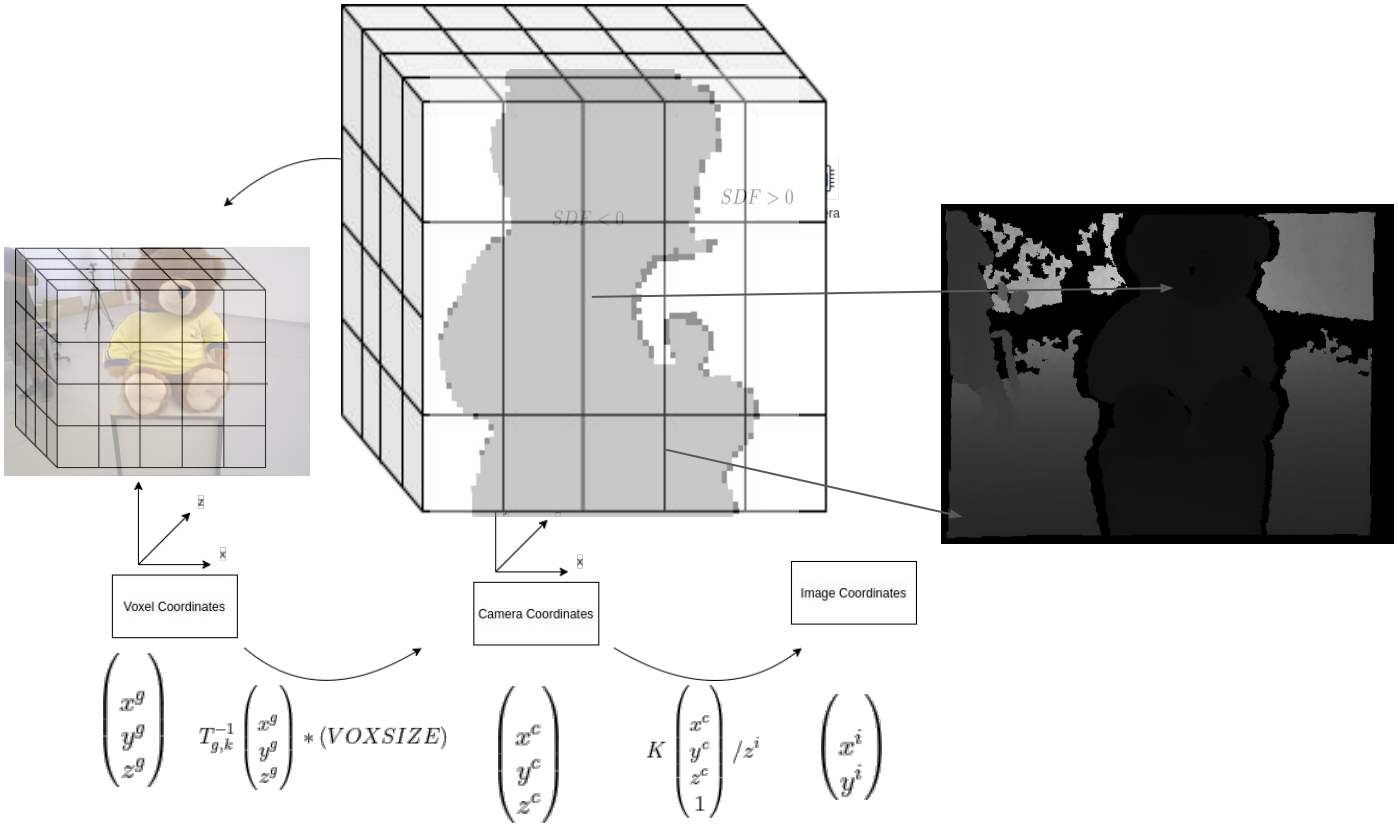


Surface prediction

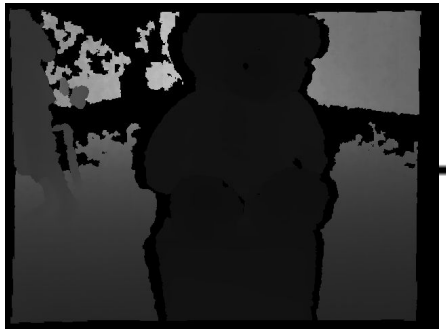
Update reconstruction



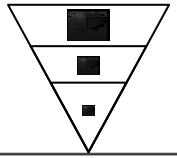
Method | Update reconstruction



Method | Surface prediction



Remove invalid mesurements



Build pyramid

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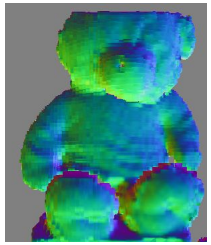
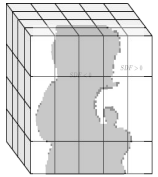


ICP

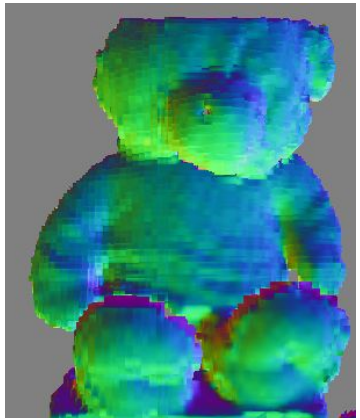
k+1

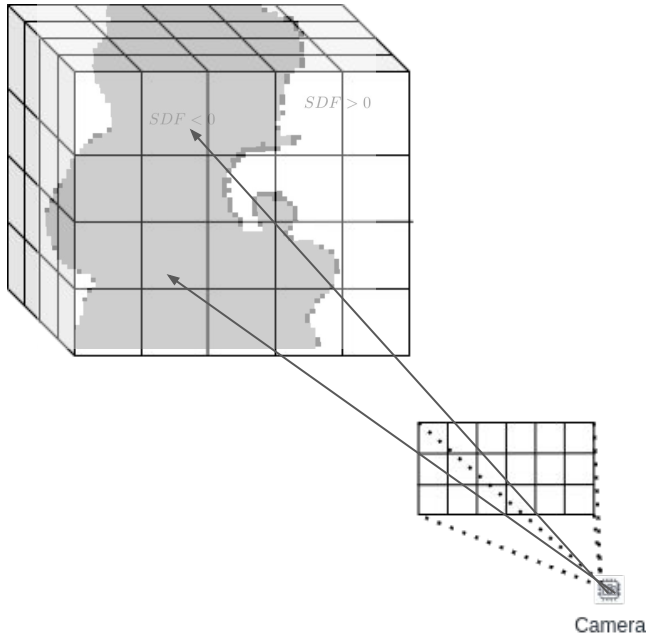
Surface prediction

Update reconstruction

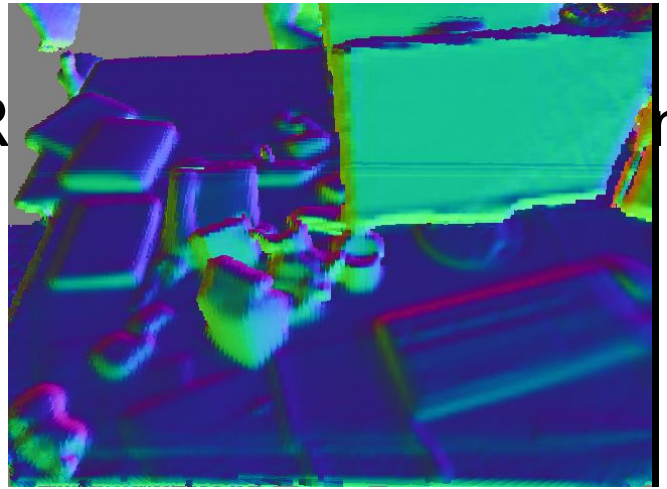


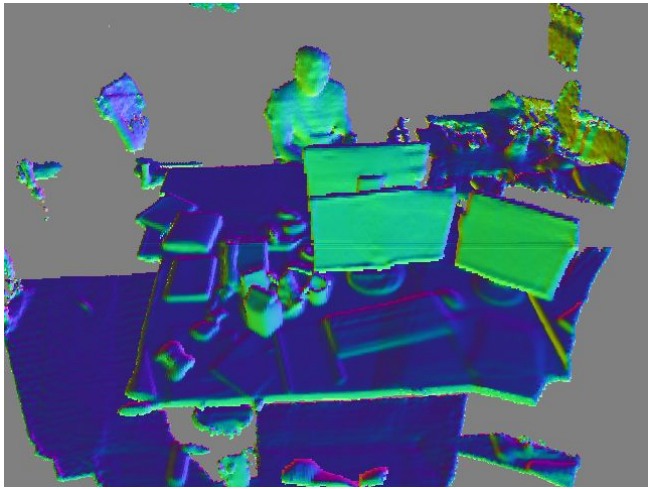
Method | Surface prediction

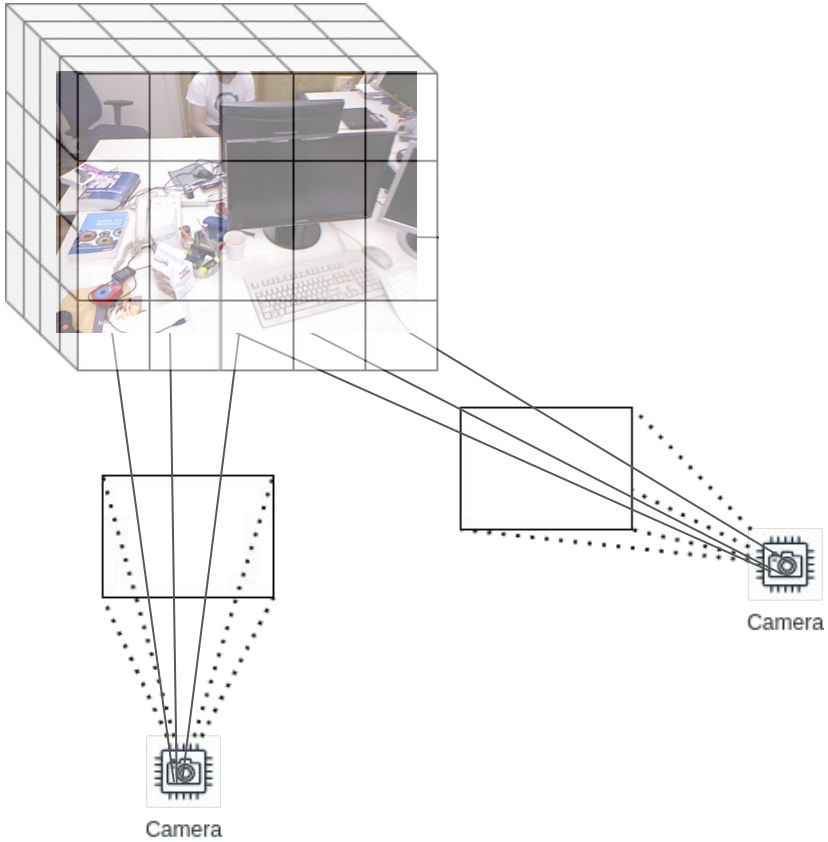




R nt viewpoints

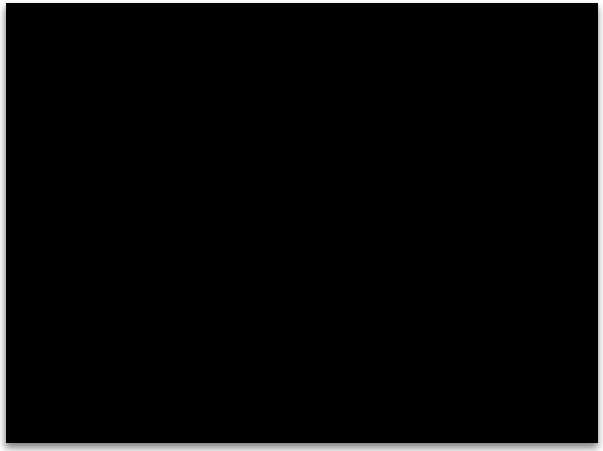




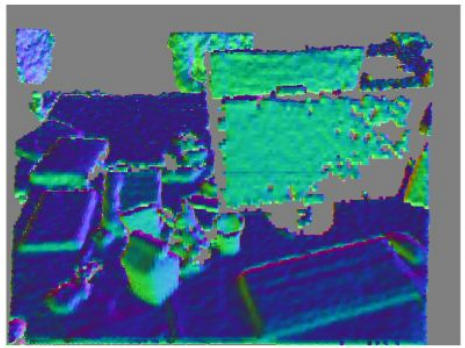
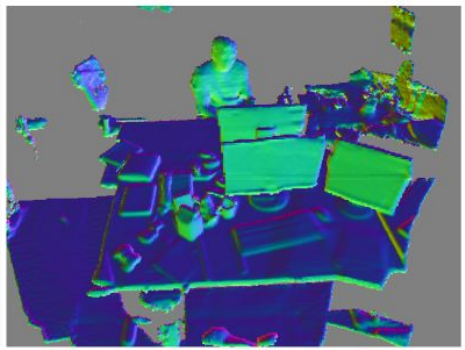
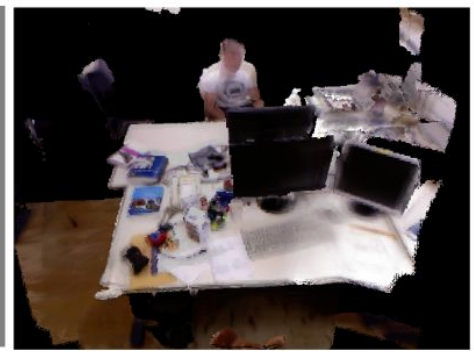


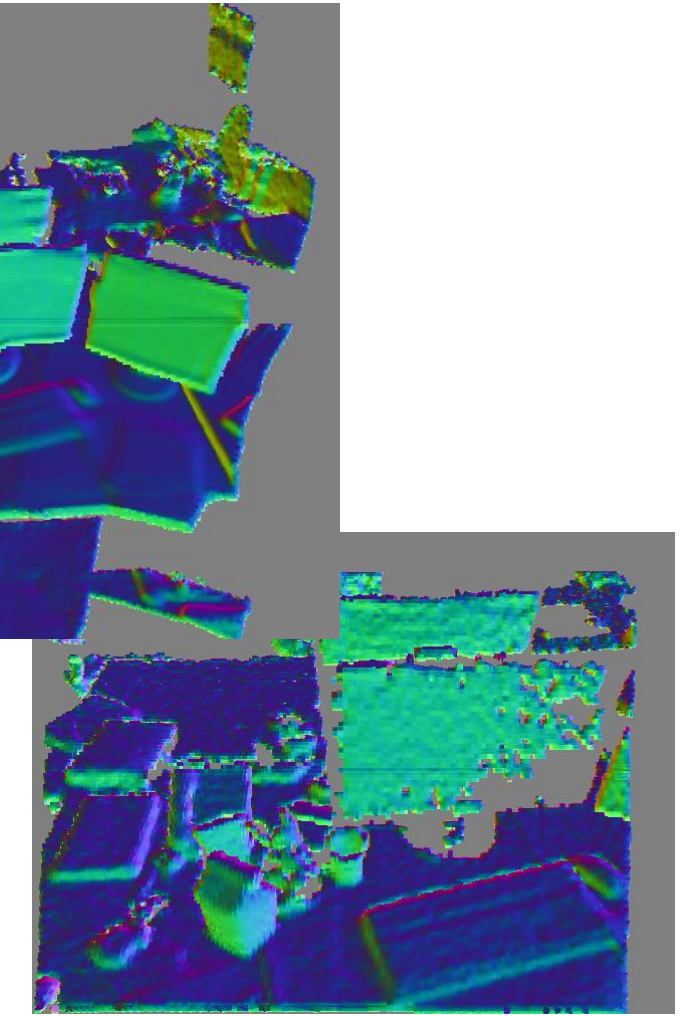
Results

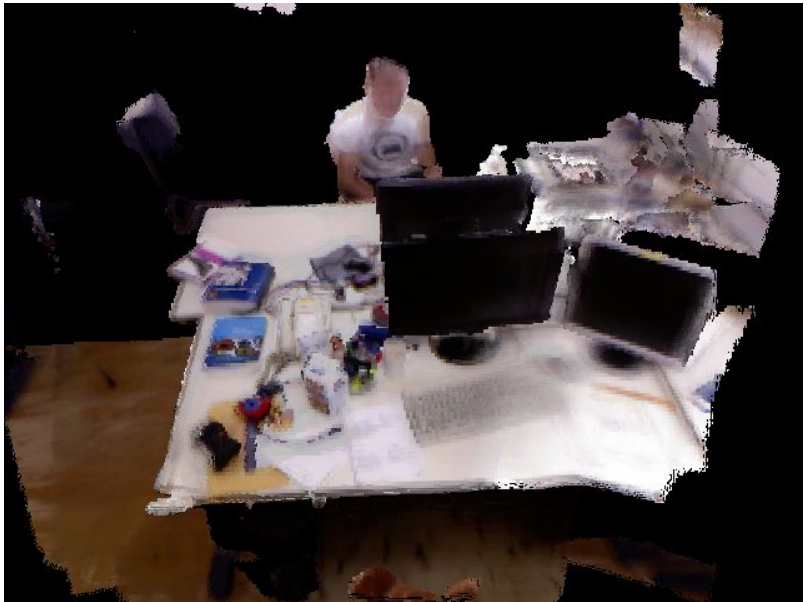


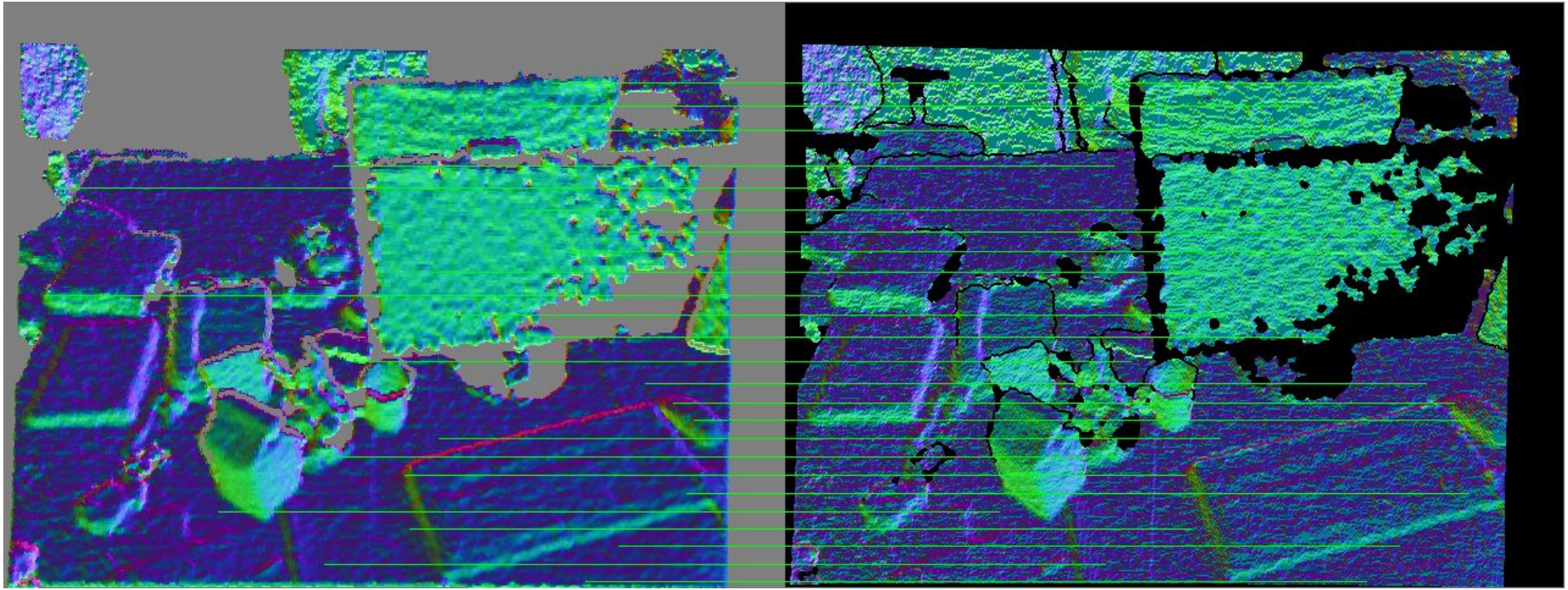


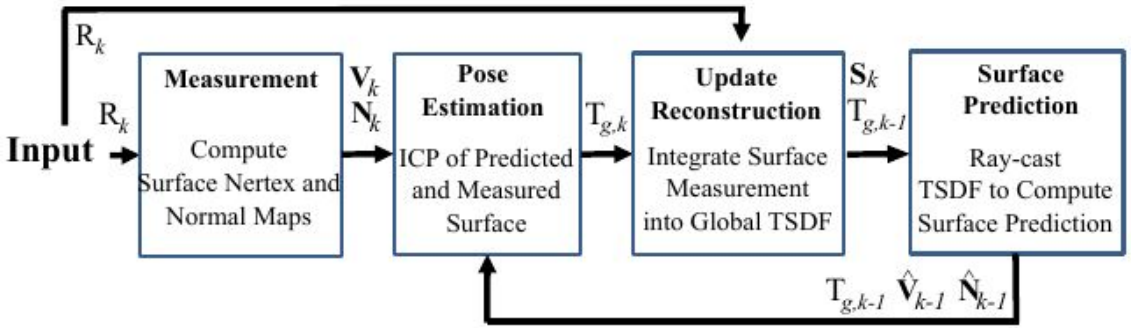


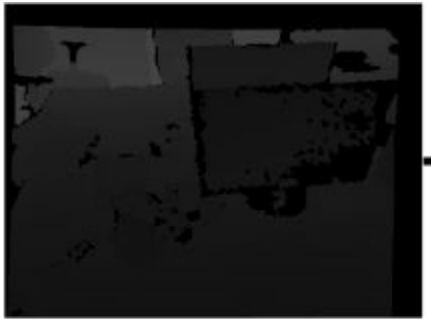











R_k
R_k
Input
Measurement
Compute Surface Nertex and Normal Maps
V_k
N_k
Pose Estimation
ICP of Predicted and Measured Surface
$T_{g,k}$
Update Reconstruction
Integrate Surface Measurement into Global TSDF
S_k
$T_{g,k-1}$
Surface Prediction
Ray-cast TSDF to Compute Surface Prediction
$T_{g,k-1}$ $\hat{V}_{k-1}$ $\hat{N}_{k-1}$



Remove invalid mesurements

Build pyramid

- Compute normal map
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- Apply bilateral filter

ICP

k+1

Surface prediction

Update reconstruction