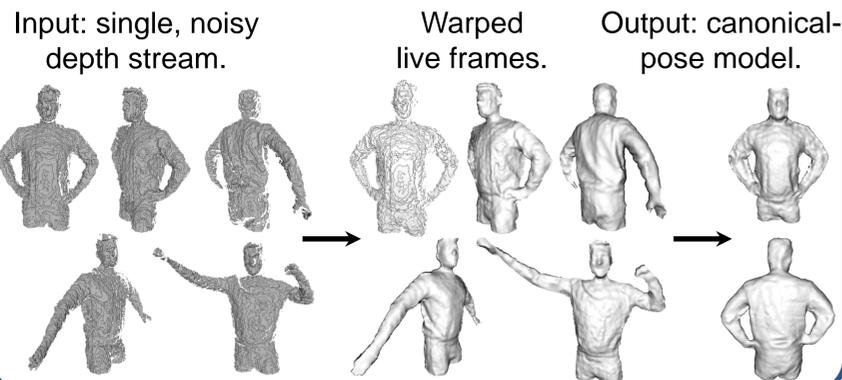


KillingFusion: Non-rigid 3D Reconstruction without Correspondences

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Task: real-time non-rigid 3D reconstruction



Objectives

- Topological changes.
- Rapid inter-frame motion.

Limitations of related approaches

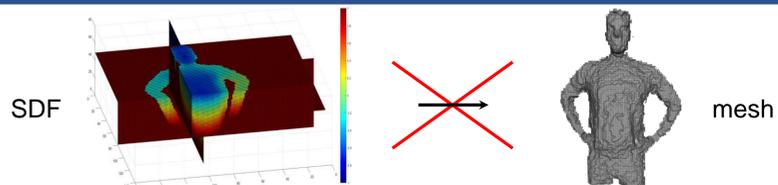
- Handle only contrived motion. [all]
- Processing takes hours. [Dou15]
- Intermittent conversion from SDF to mesh for correspondence estimation. [Newcombe15, Innmann16]
- Need to estimate a 6D deformation field. [all]

References

[Dou15] 3D Scanning Deformable Objects with a Single RGBD Sensor, CVPR 2015.
[Newcombe15] DynamicFusion: Reconstruction and Tracking of Non-rigid Scenes in Real-Time, CVPR 2015.
[Innmann16] VolumeDeform: Real-time Volumetric Non-rigid Reconstruction, ECCV 2016.



Contributions



- Full non-rigid framework based on a **single data representation** – the **signed distance field (SDF)**.
- Inherently handles topological changes.
- No correspondence estimation.
- No intermittent mesh conversion.

Proposed approach

Incremental **variational** estimation of a **3D deformation field** $\Psi = (u, v, w)$ from the projective SDF ϕ_n of the current frame towards canonical-pose model ϕ_{global} .

$$E(\psi) = E_{data}(\psi) + \omega_S E_{level_{set}}(\psi) + \omega_K E_{damped_{Killing}}(\psi)$$

- **Data term:** alignment.

$$E_{data}(\psi) = \frac{1}{2} \sum_{x,y,z} (\phi_n(x+u, y+v, z+w) - \phi_{global}(x, y, z))^2$$

- **Level set regularizer:** geometric correctness.

$$E_{level_{set}}(\psi) = \frac{1}{2} \sum_{x,y,z} (|\nabla \phi_n(x+u, y+v, z+w)| - 1)^2$$

- **Motion regularizer:** rigidity.

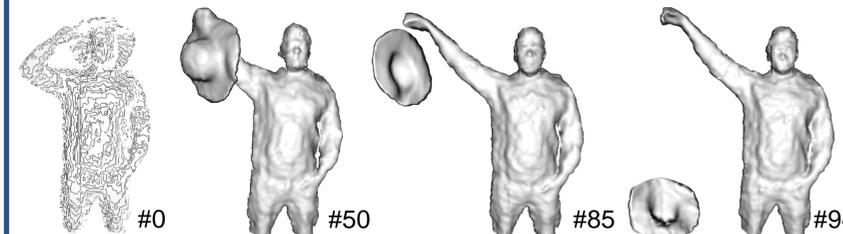
$$\text{Scene flow: } \sum_{x,y,z} (|\nabla u|^2 + |\nabla v|^2 + |\nabla w|^2) = \sum_{x,y,z} \text{vec}(J_\psi)^T \text{vec}(J_\psi)$$

$$\text{Killing vector field (divergence-free): } \frac{1}{2} \sum_{x,y,z} \|J_\psi + J_\psi^T\|_F^2 = \sum_{x,y,z} \text{vec}(J_\psi)^T \text{vec}(J_\psi) + \text{vec}(J_\psi^T)^T \text{vec}(J_\psi)$$

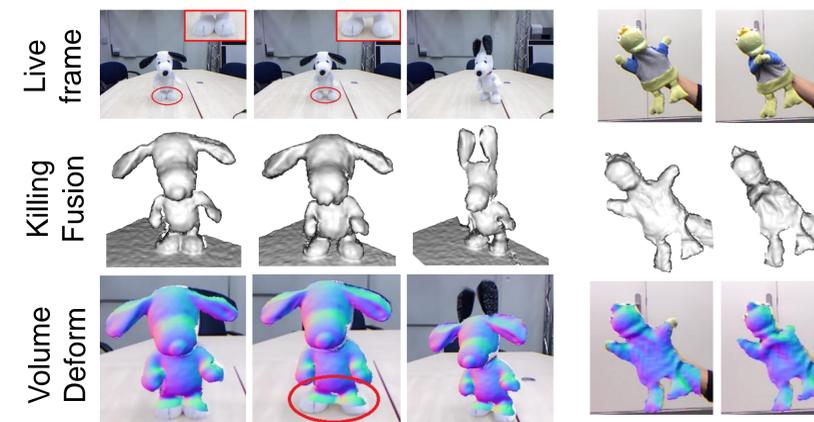
$$E_{damped_{Killing}}(\psi) = \sum_{x,y,z} \text{vec}(J_\psi)^T \text{vec}(J_\psi) + \gamma \text{vec}(J_\psi^T)^T \text{vec}(J_\psi)$$

Results

Multiple objects



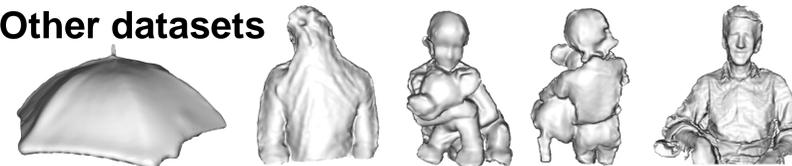
Topology changes & fast motion



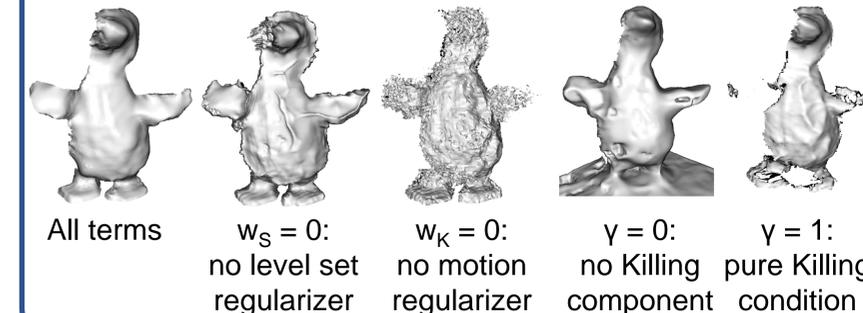
Quantitative evaluation dataset

Reconstruction error [mm]	VolumeDeform [Innmann16]	KillingFusion [ours]
Duck	5.362	3.896
Snoopy	4.205	3.543

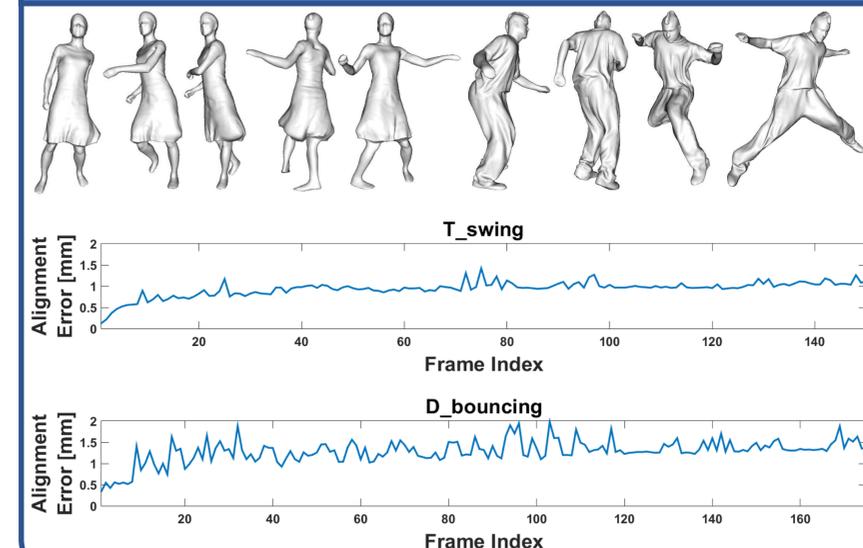
Other datasets



Effects of energy components



Full 3D



Limitations

- No correspondences – cannot propagate texture.
- Regular voxel grid – real-time limited to $\sim 80^3$ voxels.

