CSE-571
Mapping and Modeling
Using Truncated Signed Distance Functions

Based on work by Peter Henry
University of Washington

KinectFusion: Real-Time Dense Surface Mapping and Tracking.
Newcombe et al. ISMAR 2011

Raw normal map (input)  Kinect RGB (not used)

Full room reconstruction

3D reconstruction (surface normals)  3d reconstruction (L.N shaded)

Truncated Signed Distance Function (TSDF)

TSDF Surface Prediction

A regular grid holds a discretization of the SDF. Ray-casting of iso-surfaces S. (Parker et al. 1998) is an established technique in graphics.
TSDF Mesh Extraction:
Marching Cubes

Patch Volumes
• Model: A collection of fusion volumes
  – Allocate volumes based on planar patches
  – Save memory: model only occupied space
  – Enable arbitrary scale
  – Shift volumes for global consistency

Patch Volume Segmentation

Kintinuous: Spatially Extended KinectFusion.
Whelan et al. RSS RGB-D Workshop 2012
Whelan et al. ICRA 2013
Deformation-based Loop Closure for Large Scale Dense RGB-D SLAM
Whelan et al. IROS 2013 (contemporaneous)
Patch Volumes in 3D

Depth & Color Both Matter

Depth Only:

Color Only:

Global Consistency:
Patch Volumes Grow Old
Loop Closure Alignment

- Initialize with feature matching
- Run dense alignment against “old” volumes

Graph Optimization

g2o: A General Framework for Graph Optimization. Kuemmerle et al. ICRA 2011

Global Consistency Matters

No Loop Closure: With Loop Closure:
Result Overview

A More Complete Model

A More Complete Model

Thin Surfaces

Single Volume (color bleeding, size inflation)

Patch Volumes
Real-Time Reconstruction and Tracking of Non-rigid Scenes

**DynamicFusion**

*KinectFusion on a Non-rigid Scene*
Dense Non-Rigid Surface Tracking

Data($W_t, V, D_t$) : Dense Per-Pixel Data Term

Per-Pixel Projected Model-to-Frame Point-Plane Error

Reg($W_t, \mathcal{E}$) : as-Rigid-as-possible

$\Psi_{reg}(T^0_{v^0} - T^1_{v^0})$
Non-Rigid Generalisation of Range Image Fusion

- Live Depth Video
- \( W_t \) – Warp Field
- Updating Canonical Model

Algorithm Summary

- **Given:** Canonical model and warp field at previous time step

- **Update Warp Field**
  - Extract surface mesh from canonical (static) SDF model
  - Update warp nodes via non-rigid alignment to depth image

- **Update Canonical SDF Model**
  - Use updated warp field to project each SDF voxel into depth frame and update SDF value

- **Update Warp Field Structure**
  - Add new warp nodes if necessary, update regularization structure
Limitations

- Reconstruction Scalability
  - Volumetric surface representation
  - Tracking of Motion not in the live frame
- Tracking Failures
  - Closed to Open Topology Changes
  - No Explicit Loop closure

Initializing DynamicFusion

Learning to Solve Long-Range Dense Correspondence using Generatively Tracked Short-Range Non-Rigid Correspondences