Multi-View Thin Structure Reconstruction via 3D Lines and Points (#12)

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Introduction and Motivation

- Scenes with thin structures and edges are poorly reconstructed by multi-view stereo algorithms, due to appearance variation.
- We propose the integration of line segments into the SfM point-cloud via a radial sampling technique.
- We then perform dense reconstruction and mesh texturing on this combined point-cloud.
- Results highlight the recovery of thin structures, along with enhanced visibility of edges.

Pipeline

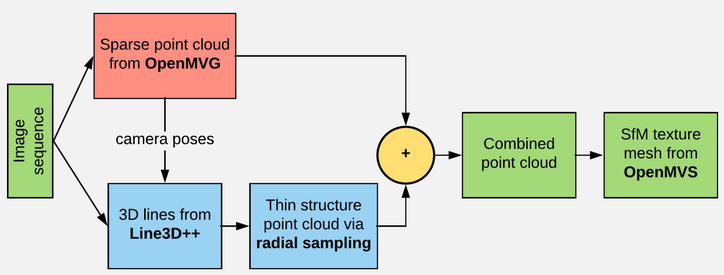

Figure 1. Incorporating thin structure modeling into a multi-view reconstruction pipeline

Global SfM

- To generate a sparse model of the 3D structure of the scene, we use the SfM library from openMVG.
- Given an unordered set of images with camera intrinsics specified, openMVG estimates the global pose P_i of each camera, and global position of features points X^j
- openMVG optimizes the following cost function:

$$\min_{P_0,\ldots,P_M,X^0,\ldots,X^N} \left[\sum_i^M \sum_j^N \left(x_i^j - KP_iX^j\right)^2\right]$$

where $\mathbf{x}_i^j$ is the image coordinate of the jth feature point in the ith camera.

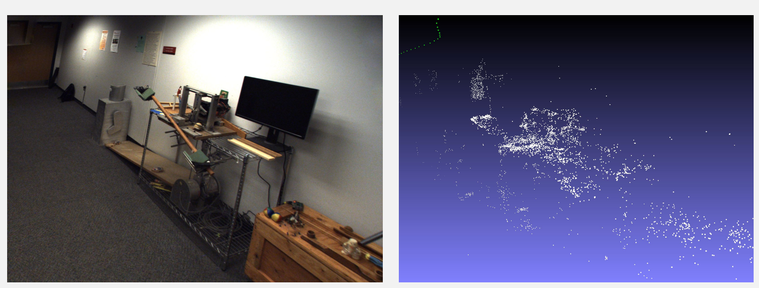

Figure 2. Image of scene and optimized sparse 3D points

[1] Moulon, Pierre, Pascal Monasse, and Renaud Marlet. "Global fusion of relative motions for robust, accurate and scalable structure from motion." *Proceedings of the IEEE ICCV*. 2013.
[2] Manuel Hofer, Michael Maurer, and Horst Bischof. Line3d: Efficient 3d scene abstraction for the built environment. In German Conference on Pattern Recognition, pages 237-248. Springer, 2015.
[3] Jancosek, Michal, and Tomas Pajdla. "Exploiting visibility information in surface reconstruction to preserve weakly supported surfaces." *International scholarly research notices* 2014 (2014).

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Line-based 3D Model

- From the SfM output, we get the ordered image sequence sparse point cloud and visibility information.

$$\mathbf{I} = \{I_1, \ldots, I_N\} \qquad \mathbf{X} = \{X_1, \ldots, X_K\}$$

- We use Line3D++, a pipeline to abstract 3D scene information using line segments.
- We run a line segment detector on every image, establish correspondences across images with *supporting views*.

$$S_I(i,j) = \frac{2|X(i) \cap X(j)|}{|X(i)| + |X(j)|}$$

- Generate 3D hypothesis based on plausible correspondences; cluster the 2D segments based on them.
- Refine estimate to get final 3D line model.

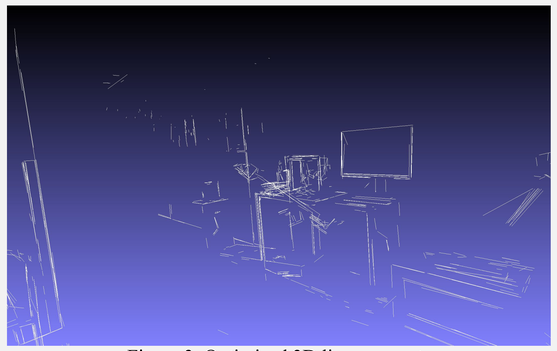

Figure 3. Optimized 3D line segments

Thin Structure Sampling Strategy

- For each line segment represented by points P_1 and P_2, we sample $N = \text{round}\,(mL)$ points on the cylinder of radius r around the segment, where $L = ||P_1 - P_2||_2$ and m is a scaling factor.
- We do this by sampling N angles $\theta_i \in [-\pi, \pi]$ and N lengths $s_i \in [0, L]$ and computing the corresponding 3D points.

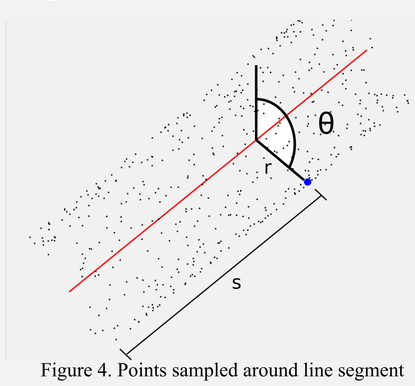

Figure 4. Points sampled around line segment

Dense Reconstruction

We use openMVS to convert our sparse point cloud to a dense 3D mesh. The components of the pipeline are:

- Densify the sparse point cloud with patch match algorithm
- Use visibility information in a graph-cut algorithm to reconstruct a mesh from the densified points
- Refine the mesh by subdividing triangles based on size and visibility information
- Texture the mesh using the original images

Results

We evaluate our method on our `nsh_a_floor` dataset. The reconstructions recover many structures and edges that are lost in the standard pipeline.

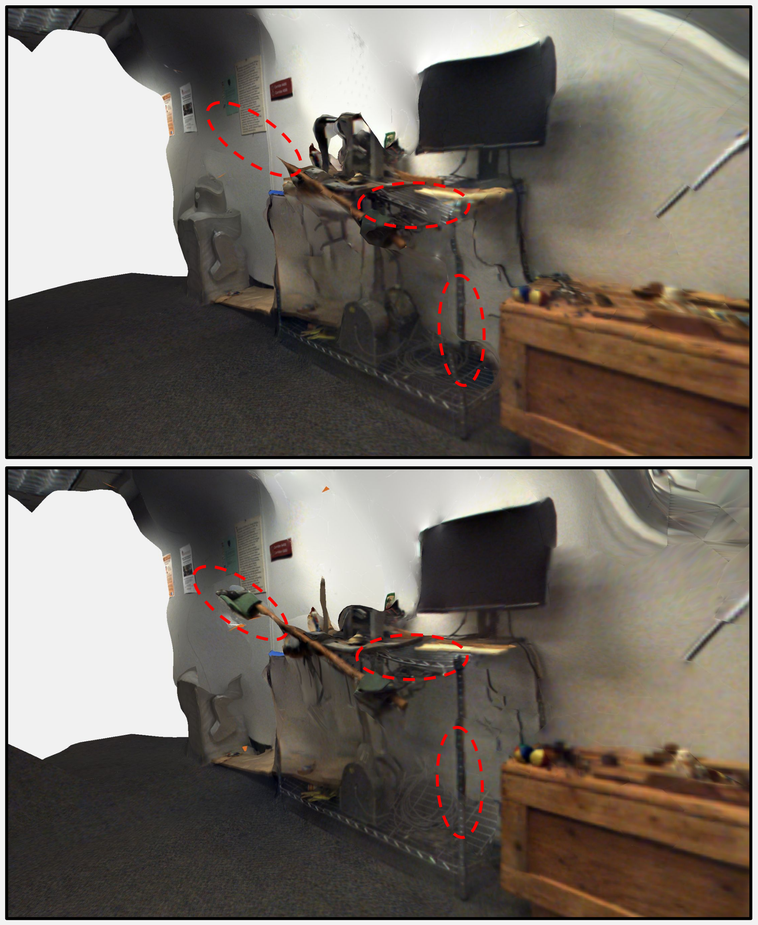

Figure 6. Final textured meshes from the **(top)** standard pipeline and **(bottom)** our pipeline. We improve reconstruction of thin structures - we recover the end of the object, along with a better reconstructed frame.

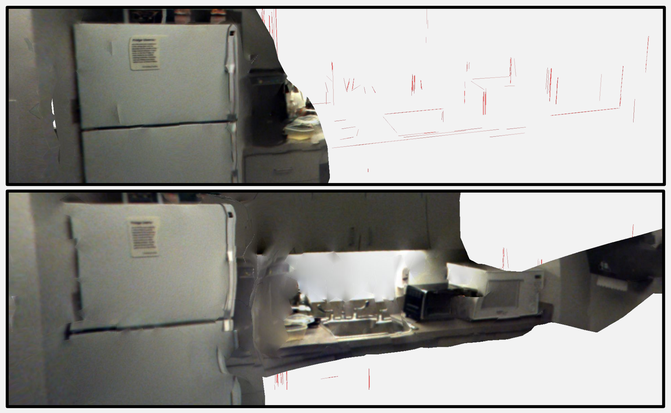

Figure 6. Line features are matched more robustly, leading to improved coverage and alignment in the final reconstruction

Future Work

- Fitting splines to clustered line segments will better model curved surfaces
- Separate treatment of thin and regular structures will allow for optimum parameter tuning during dense reconstruction
- Evaluation on scenes with objects of varying shape and size