Occluding Contours for Multi-View Stereo

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Problem

Internet photos collections often result in unsatisfactory geometry reconstructions. The failure shows up as *noisy surface details* and *boundary artifacts*.
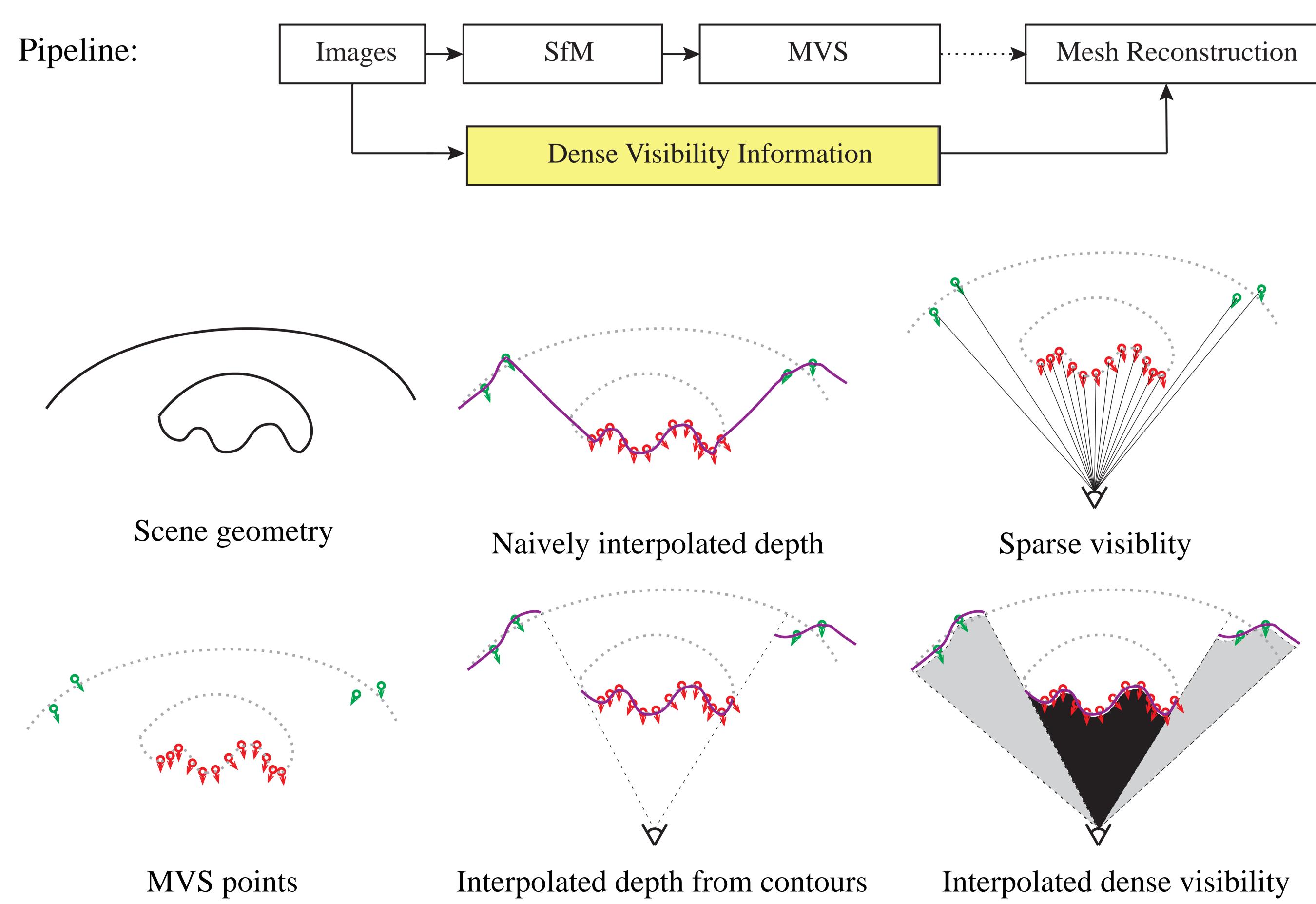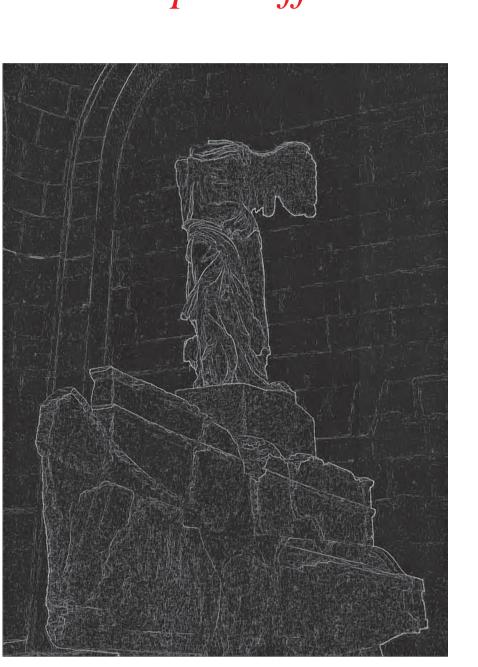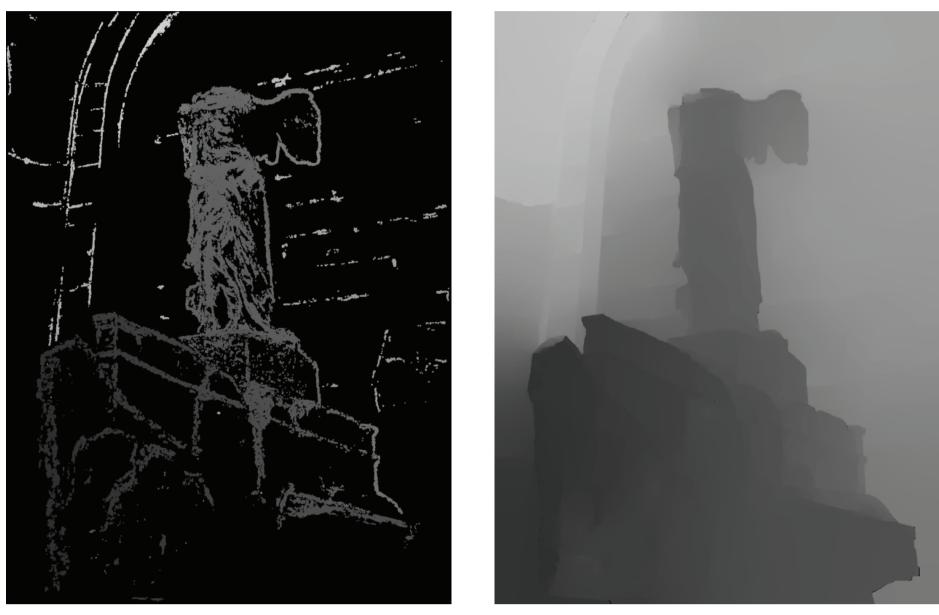

PMVS + Poisson   Proposed   [Shan et al. 2013]   Proposed

Solution: Estimating dense **visibility** information from occluding contours.

Contributions

This work leverages *occluding contours* (aka "internal contours") to improve the performance of MVS methods. The contributions are
(i) identifying free-space regions arising from occluding contours,
(ii) incorporating the free-space constraints into Poisson surface reconstruction.

Pipeline:

Images → SfM → MVS ⋯⋯ Mesh Reconstruction

Dense Visibility Information

Scene geometry   Naively interpolated depth   Sparse visiblity

MVS points   Interpolated depth from contours   Interpolated dense visibility

Interpolating depth maps

$$E_d \;=\; \sum_{x,y \in \Omega} \underbrace{(d_{x,y} - \hat{d}_{x,y})^2}_{\text{depth difference}} + \lambda \sum_{x,y} \underbrace{w_x(x,y)\left(\frac{\partial^2 d_{x,y}}{\partial x^2}\right)^2 + w_y(x,y)\left(\frac{\partial^2 d_{x,y}}{\partial y^2}\right)^2}_{\text{weighted by contour response}}$$

Input image   Contour response   Initial depth   Interpolated depth   Single view rendering

Enhanced Poisson reconstruction

Input: (1) **augmented point set**, (2) **the free space volume**

$$E(\chi) = \underbrace{\int \|\nabla \chi(u) - V(u)\|^2 du}_{\text{Poisson term}} + \underbrace{\alpha \frac{A}{|\mathcal{P}|} \sum_{p \in \mathcal{P}} c(p)\chi^2(p)}_{\text{screen term}} + \underbrace{\beta \int_{u \in V_f} \|\chi(u) - 1\|^2 du}_{\text{free space term}}.$$

Augmenting 3D points

1) Combining all per-view point sets
2) Removing points
   (a) of low confidence
   (b) in the free space (significant visibility conflict)
   (c) not on the surface
3) Adding original PMVS points back

Initial points (PMVS)   Augmented points

Constructing free space volume

1) Back-project interpolated depth maps
2) Vote for free voxels based on accumulated confidence
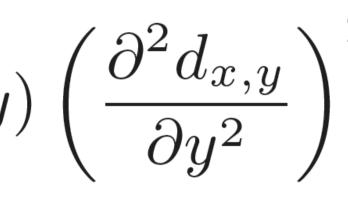
Seeding and refining sky masks
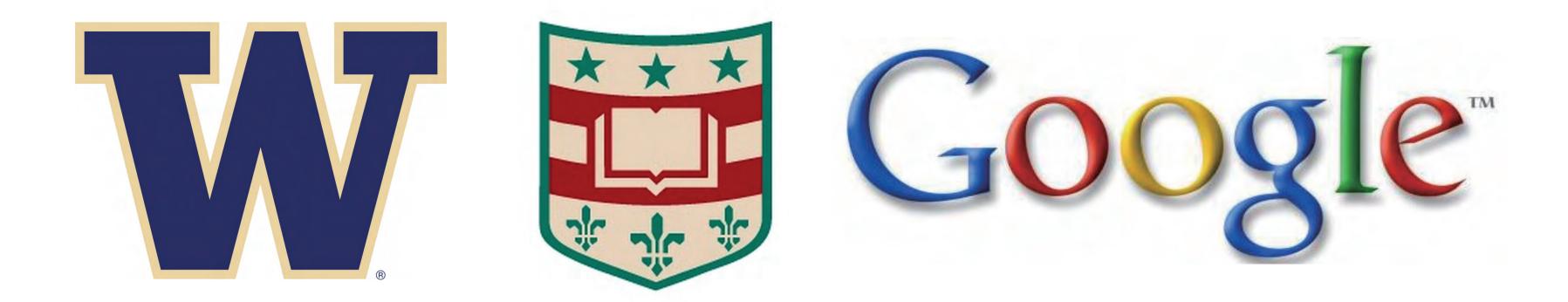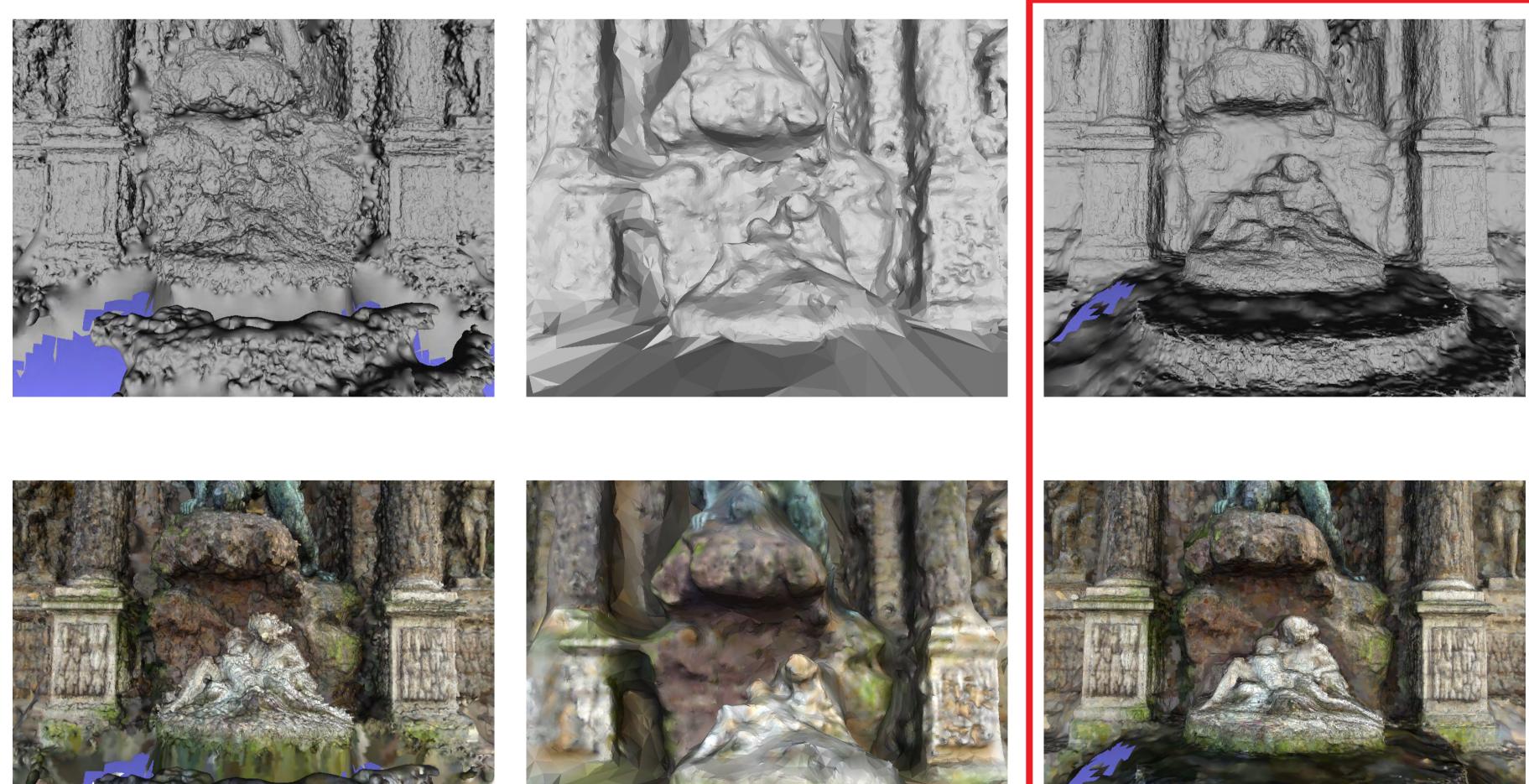

Input image   Initial sky silhouettes   Refined sky mask

Initializing sky mask by:
1) geometry reasoning from
    initial Poisson mesh
2) color reasoning
    (sky is gray or blue)

Results

Sample input image

PMVS point cloud

Sample input   Initial depth   Interpolated depth   PMVS + Poisson   [Jancosek et al. 2012]   Proposed approach

Sample input image

PMVS point cloud   PMVS + Poisson   [Jancosek et al. 2012]   Proposed approach

PMVS + Poisson   Proposed   [Shan et al. 2013]   Proposed