Point Cloud Noise and Outlier Removal for Image-Based 3D Reconstruction – Supplementary Material –

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In this supplementary material, we first present the parameters used to create the meshes in Figure 4 of our paper with the screened Poisson surface reconstruction (PSR) method.

We then provide pseudocode for our noise and outlier removal algorithm. Finally, we present each dataset from Figure 4 of the paper in a more extensive manner.

For each reconstruction method (MVE, LFD, ACTS and PS) we show the unfiltered reconstructed point cloud, the triangle mesh constructed from this point cloud using PSR, the filtered point cloud using our outlier and noise removal algorithm, and the resulting mesh constructed by PSR. For PMVS, we show the reconstructed point cloud and the corresponding mesh only as a comparison. As PMVS does not produce depth maps, we cannot apply our algorithm here. **Please also refer to the supplementary video for a presentation of the results from Figure 4.**

PSR parameters for Figure 4 in our paper

Datasets	MVE				LFD				ACTS				PS				PMVS	
	PSR		**Ours+PSR**		PSR		**Ours+PSR**		PSR		**Ours+PSR**		PSR		**Ours+PSR**		PSR	
	pw	*spn*	*pw*	*spn*	*pw*	*spn*	*pw*	*spn*	*pw*	*spn*	*pw*	*spn*	*pw*	*spn*	*pw*	*spn*	*pw*	*spn*
DECORATION	0	5	1	5	0	20	0	20	0	20	0.1	5	0	20	0	20	0.25	1
DRAGON	0	5	1	3	0.1	20	1	5	0	5	4	3	0	20	0	20	0.5	1
SCARECROW	0	5	1	3	0.1	20	0	5	0.1	10	1	20	0	10	1	20	1	1
STATUE	0.1	1	4	10	0.1	10	1	20	0.1	20	0.1	3	0	5	1	20	0.25	1
TORCH	0	3	1	1	0	5	0	1	0	5	0	5	0	20	1	20	0.25	1

Table 1: Parameters used for generating meshes using PSR from the point clouds without (*columns titled PSR*) and with (*columns titled Ours+PSR*) our denoising method, in Figure 4 of our paper. Here, *pw* denotes the chosen point weight and *spn* denotes the samples per node.

References

[1] H. Hoppe, T. DeRose, T. Duchamp, J. McDonald, and W. Stuetzle. Surface reconstruction from unorganized points. In *Proc. ACM SIGGRAPH*, pages 71–78, 1992. 7

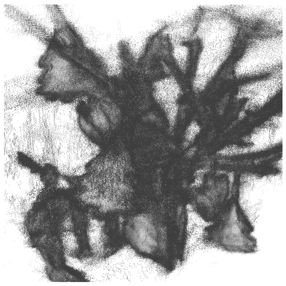
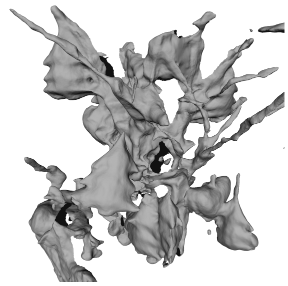
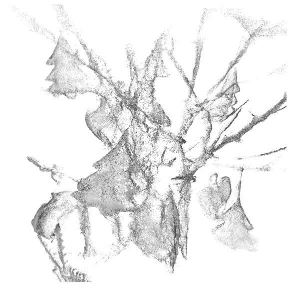
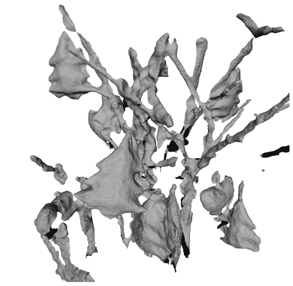
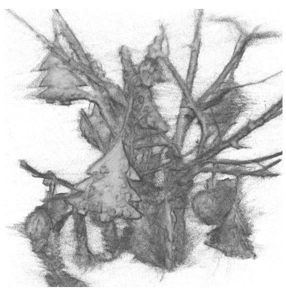
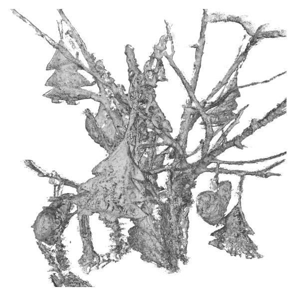
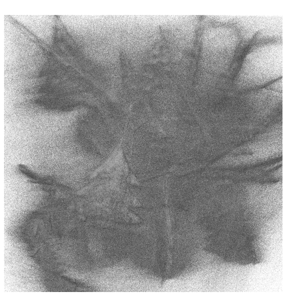
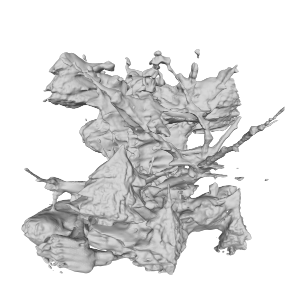
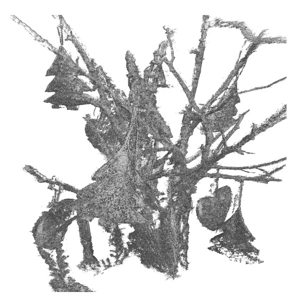
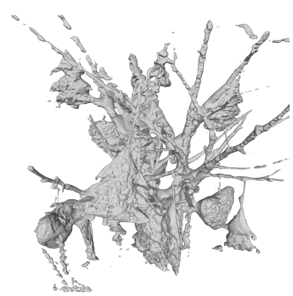
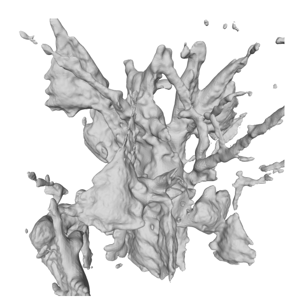
	point cloud	PSR	filtered point cloud	PSR on filtered point cloud
MVE				
LFD				
ACTS				
PS				
PMVS				

Table 2: Results for the DECORATION dataset.

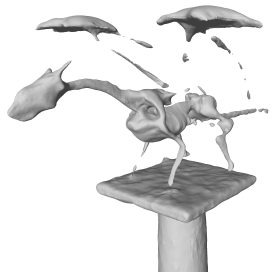
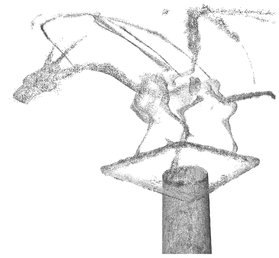
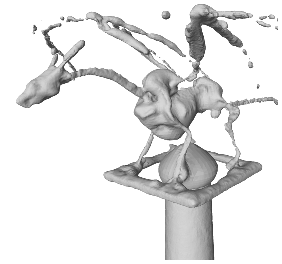
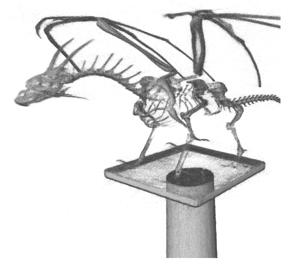
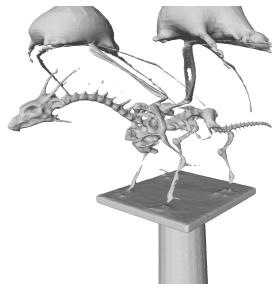
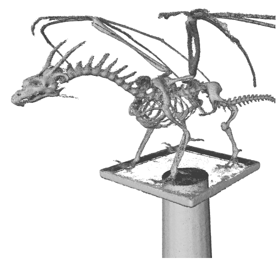
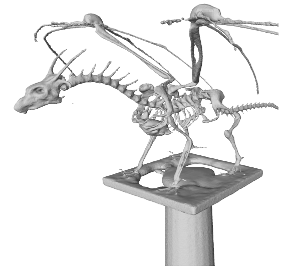
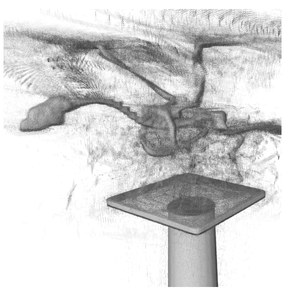
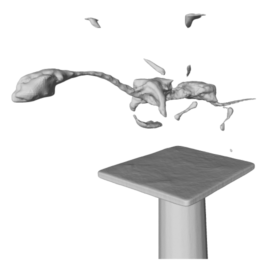
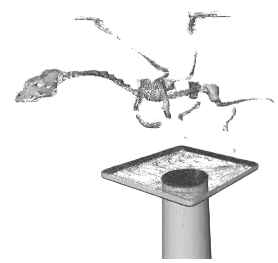
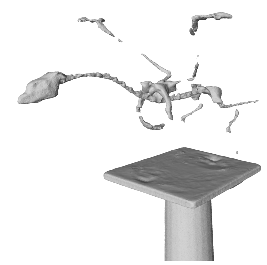
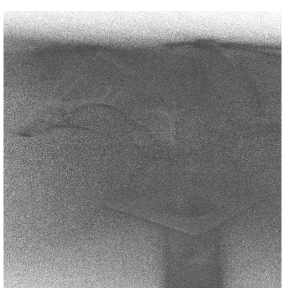
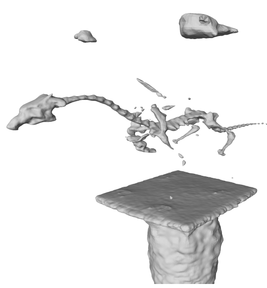
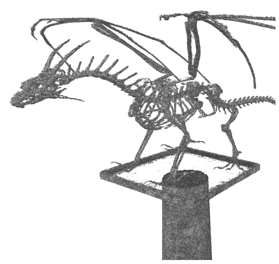
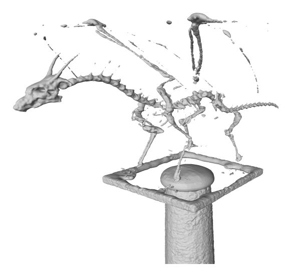
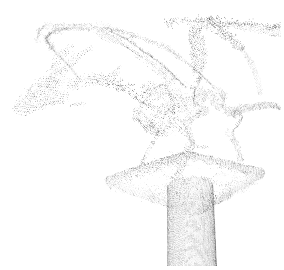
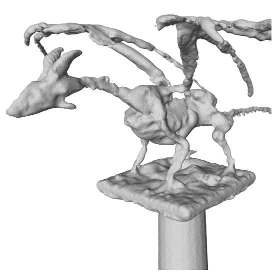
	point cloud	PSR	filtered point cloud	PSR on filtered point cloud
MVE				
LFD				
ACTS				
PS				
PMVS				

Table 3: Results for the DRAGON dataset.

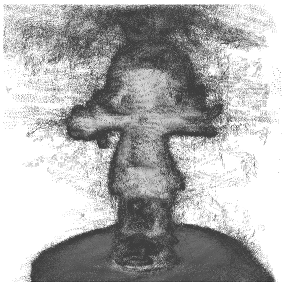
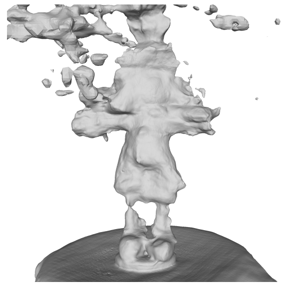
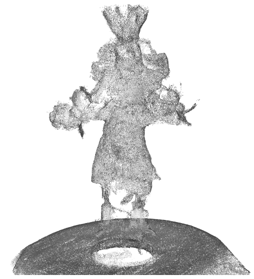
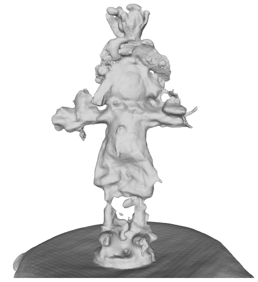
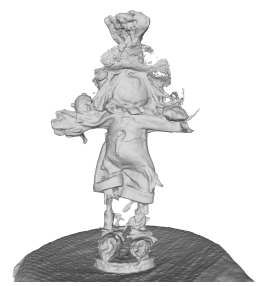
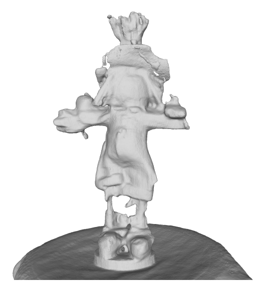
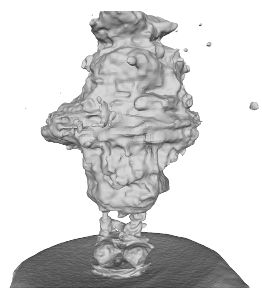
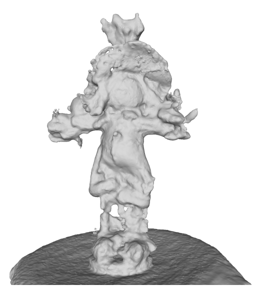
	point cloud	PSR	filtered point cloud	PSR on filtered point cloud
MVE				
LFD				
ACTS				
PS				
PMVS				

Table 4: Results for the SCARECROW dataset.

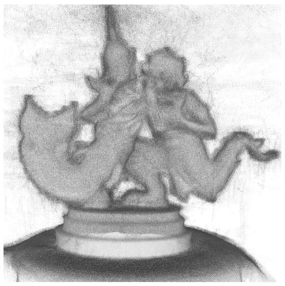
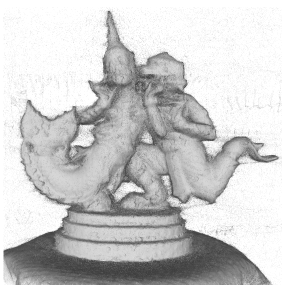
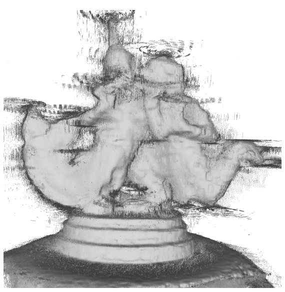
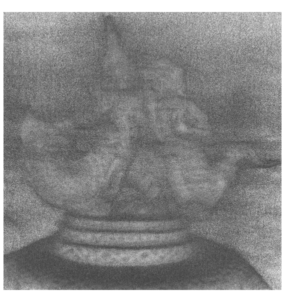
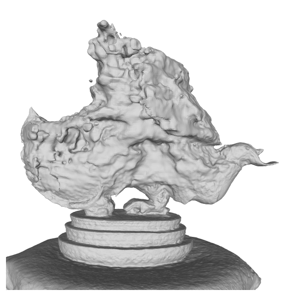
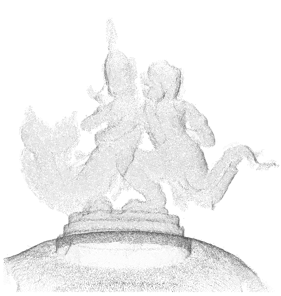
	point cloud	PSR	filtered point cloud	PSR on filtered point cloud
MVE				
LFD				
ACTS				
PS				
PMVS				

Table 5: Results for the STATUE dataset.

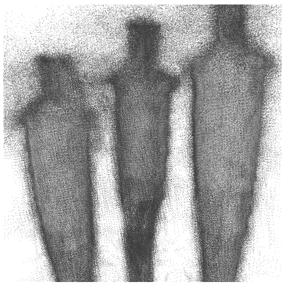
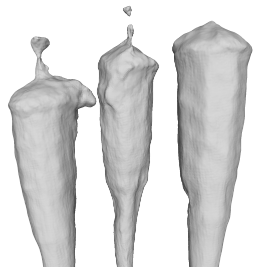
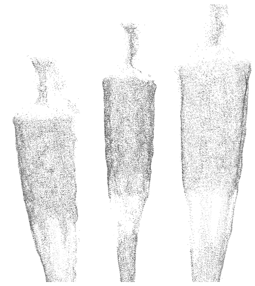
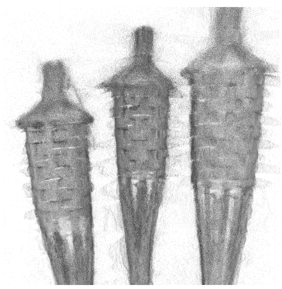
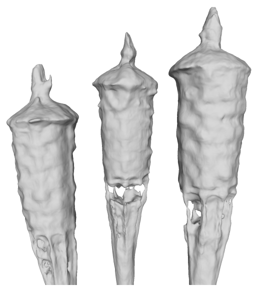
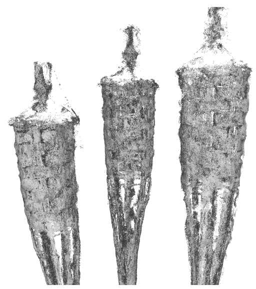
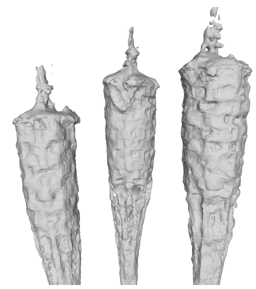
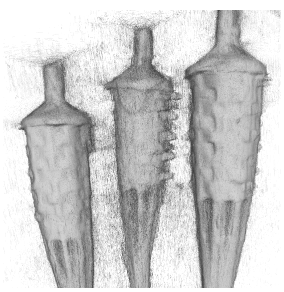
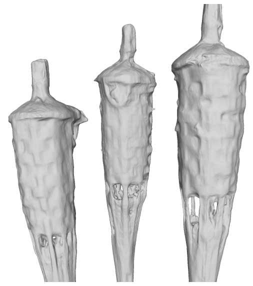
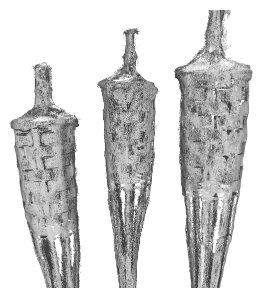
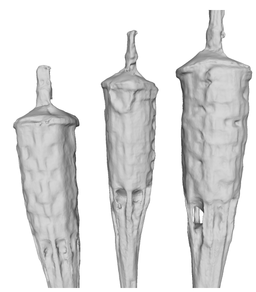
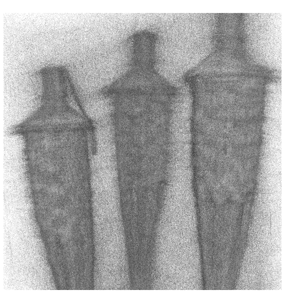
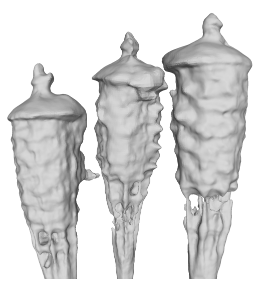
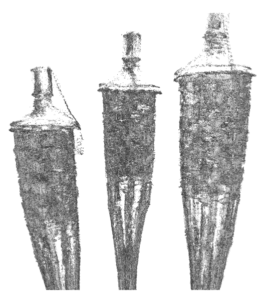
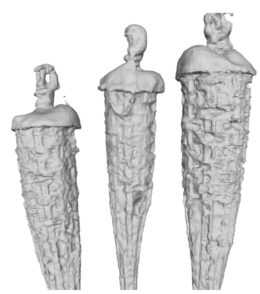
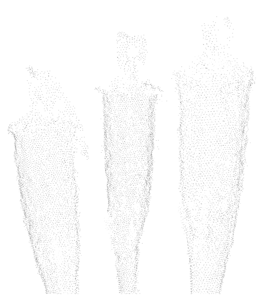
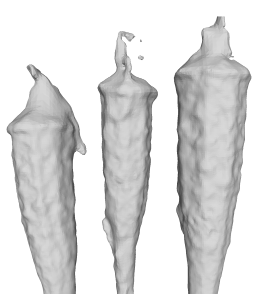
	point cloud	PSR	filtered point cloud	PSR on filtered point cloud
MVE				
LFD				
ACTS				
PS				
PMVS				

Table 6: Results for the TORCH dataset.

Algorithm 1: Pseudocode for our noise and outlier removal algorithm.

Please refer to Section 3 in our paper for more details.

input : N depth maps D_i, N camera matrices P_i (including the camera view vectors $\mathbf{v}_i$), N RGB images I_i, parameters: σ, t_d, t_p, t_v

output : filtered 3D points with normals

forall the *depth maps* D_i **do**

- $\{\mathbf{p}\} \leftarrow$ project all pixels of D_i into 3D (using camera matrices P_i);
- **forall the** *3D points* $\mathbf{p}$ *of* D_i **do**
  - compute normal (using PCA on a patch of size 7×7) `// refer to [1]`
  - compute weights $w_i(\mathbf{p})$ from normals `// see Equation 3`

filtered_points $\leftarrow \emptyset$

forall the *depth maps* D_i **do**

- **forall the** *3D points* $\mathbf{p}$ *of* D_i **do**
  - $d(\mathbf{p}), w(\mathbf{p}), v(\mathbf{p}), s, s2 \leftarrow 0$
  - **forall the** *depth maps* D_j **do**
    - $(u,v,z) \leftarrow$ project $\mathbf{p}$ into D_j (using camera matrices P_i) `// here u and v denote the coordinates in image space and z denotes the depth value`
    - get the triangle in which (u, v) is contained `// see Figure 2: this means checking whether (u,v) is contained in image space and determining three integer coordinates for the triangle corners - an upper left triangle or a lower right triangle`
    - **if** $\mathbf{v}_i^\mathsf{T}\mathbf{v}_j > 0$ ***or*** *(u,v) lies in no triangle* ***or*** *the smallest angle of the triangle < 1 degree* **then**
      - continue
    - interpolate weight w from triangle corner weights $w_i(\mathbf{p})$ `// see Figure 2`
    - interpolate depth value $z(\mathbf{p})$ from the depth values of triangle vertices `// see Figure 2`
    - $d \leftarrow z(\mathbf{p}) - z$
    - **if** $d < -\sigma$ **then** `// p could not have been observed from this view`
      - continue
    - **if** $d > \sigma$ **then** `// p is far from the observed range surface, therefore truncate d`
      - $d \leftarrow \sigma$
    - $d(\mathbf{p}) \leftarrow \frac{w(\mathbf{p})d(\mathbf{p})+(wd)/\sigma}{w(\mathbf{p})+w}$ `// see Equation 4`
    - $w(\mathbf{p}) \leftarrow w(\mathbf{p}) + w$
    - **if** $d \neq \sigma$ **then** `// update photoconsistency only for range surfaces close to p`
      - interpolate color value $\mathbf{c}$ from the color values of triangle vertices (from the RGB image I_j); `// see Figure 2`
      - $s \leftarrow s + c$
      - $s2 \leftarrow s2 + c^\mathsf{T} c$
      - $v(\mathbf{p}) = v(\mathbf{p}) + 1$
  - $p(\mathbf{p}) = \sqrt{(s2 - s^\mathsf{T} s/v(\mathbf{p}))/v(\mathbf{p})} \cdot \frac{2}{255\sqrt{3}}$ `// see Equation 7; scaled to [0,1]`
  - **if** $-t_d < d(\mathbf{p}) < 0$ ***and*** $p(\mathbf{p}) < t_p$ ***and*** $v(\mathbf{p}) > t_v$ **then**
    - filtered_points $\leftarrow$ filtered_points $\cup$ $\mathbf{p}$

return filtered_points