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# SDFoam: Signed-Distance Foam for explicit surface reconstruction

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## Overview

Figure 1: Existing methods in literature reconstruct 3D scenes either by employing explicit or implicit geometry, each with their own advantages and drawbacks. Our method, **SDFoam**, jointly learns a signed distance field (SDF) and a 3D Voronoi Diagram (or foam), both of which are optimized during a ray-tracing process. Our method offers a good trade-off of rendering speed, visual fidelity and reconstruction accuracy.

## Our contribution

- A **single representation** for view synthesis and geometry, producing cleaner, view-consistent surfaces with fewer artifacts.
- Novel **hybrid implicit-explicit** representation combines the Voronoi Diagram with SDF for better geometry alignment.
- Enables fast mesh extraction, up to **5× faster** than a naive density-based thresholding on Radiant Foam (RF).

## Architecture

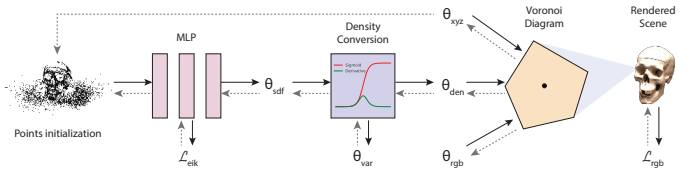


Figure 2: **SDFoam Architecture**. A point cloud is initialized and refined over time by learning an SDF from its points. Their SDF values are then converted to density, which are used jointly with color and position parameters to learn a ray-traced scene.

## Results - Novel View Synthesis

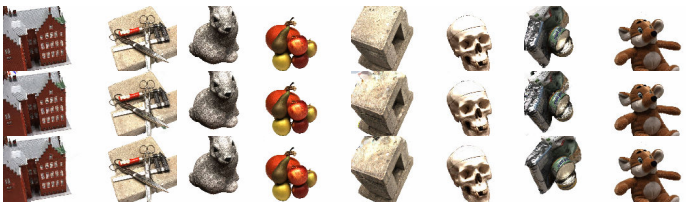

Figure 3: Novel View synthesis. Top: Ground truth. Center: RF. Bottom: SDFoam.

| Scan ID | 24 | 37 | 40 | 55 | 63 | 65 | 69 | 83 | 97 | 105 | 106 | 110 | 114 | 118 | 122 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PSNR ($RF_M$) | 24.36 | 22.39 | 26.34 | **26.77** | 28.38 | 24.81 | 22.96 | 28.33 | 21.33 | 27.03 | 23.72 | 24.21 | 24.78 | 25.93 | 28.84 | 25.34 |
| PSNR ($SDFoam_M$) | **25.59** | **24.96** | **26.55** | 26.27 | **28.81** | **25.78** | **23.77** | **28.90** | **26.12** | **28.30** | **24.08** | **25.80** | **27.13** | **27.58** | **29.29** | **26.60** |
| SSIM ($RF_M$) | 0.796 | 0.770 | **0.823** | **0.925** | **0.942** | 0.901 | **0.880** | **0.952** | 0.839 | **0.917** | **0.892** | **0.907** | 0.866 | **0.927** | 0.938 | 0.885 |
| SSIM ($SDFoam_M$) | **0.803** | **0.828** | 0.814 | 0.900 | 0.937 | **0.911** | 0.870 | 0.949 | **0.904** | 0.914 | 0.886 | 0.904 | **0.884** | 0.922 | **0.939** | **0.891** |

Figure 4: Our joint Voronoi-SDF formulation achieves better results and acts as an additional regularization to boost visual appearance, removing occasional floaters in the scene, as shown in Fig. 3.

## Qualitative Results

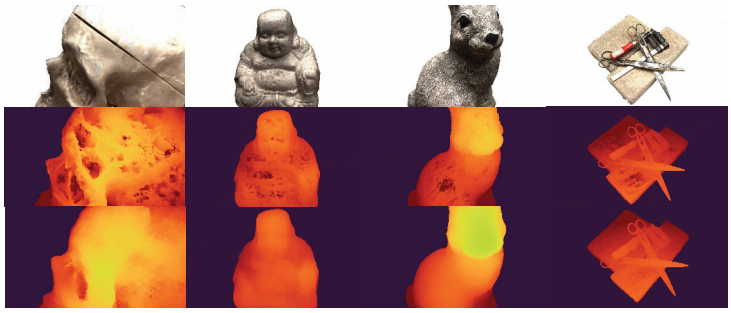

Figure 5: Mesh reconstruction qualitative results. Top to bottom: ground truth, Radiant Foam, SDFoam. Modelling the voronoi cells as local SDFs improves the consistency of the extracted surface, thus filling the typical *holes* derived from the ray-tracing procedure in Radiant Foam.

## Results - 3D Reconstruction

| | Chamfer Distance (w/ mask) ↓ | | | | | PSNR ↑ | | SSIM ↑ | |
|---|---|---|---|---|---|---|---|---|---|
| ScanID | IDR | NeRF | NeuS | RF* | SDFoam | RF | SDFoam | RF | SDFoam |
| scan24 | 1.63 | 1.83 | 0.83 | 6.13 | 1.86 | 31.28 | 29.80 | 0.877 | 0.848 |
| scan37 | 1.87 | 2.39 | 0.98 | 3.53 | 2.87 | 31.58 | 30.42 | 0.921 | 0.899 |
| scan40 | 0.63 | 1.79 | 0.56 | 6.02 | 1.80 | 32.12 | 30.68 | 0.886 | 0.851 |
| scan55 | 0.48 | 0.66 | 0.37 | 1.31 | 0.86 | 33.04 | 32.01 | 0.957 | 0.946 |
| scan63 | 1.04 | 1.79 | 1.13 | 7.10 | 2.23 | 35.97 | 35.26 | 0.969 | 0.962 |
| scan65 | 0.79 | 1.44 | 0.59 | 2.10 | 1.52 | 32.96 | 32.43 | 0.958 | 0.952 |
| scan69 | 0.77 | 1.50 | 0.60 | 2.84 | 1.30 | 29.18 | 28.17 | 0.937 | 0.907 |
| scan83 | 1.33 | 1.20 | 1.45 | 7.54 | 1.27 | 33.10 | 32.82 | 0.974 | 0.970 |
| scan97 | 1.16 | 1.96 | 0.95 | 5.41 | 1.53 | 31.25 | 30.12 | 0.974 | 0.931 |
| scan105 | 0.76 | 1.27 | 0.78 | 8.16 | 2.16 | 32.37 | 32.15 | 0.953 | 0.945 |
| scan106 | 0.67 | 1.44 | 0.52 | 6.79 | 1.67 | 29.08 | 28.41 | 0.948 | 0.931 |
| scan110 | 0.90 | 2.61 | 1.43 | 2.54 | 3.03 | 29.86 | 29.37 | 0.954 | 0.941 |
| scan114 | 0.42 | 1.04 | 0.36 | 1.78 | 1.15 | 32.28 | 31.01 | 0.946 | 0.930 |
| scan118 | 0.51 | 1.13 | 0.45 | 1.96 | 1.52 | 31.73 | 31.01 | 0.968 | 0.951 |
| scan122 | 0.53 | 0.99 | 0.45 | 1.82 | 1.34 | 34.82 | 34.12 | 0.976 | 0.969 |
| mean | 0.90 | 1.54 | 0.77 | 4.33 | 1.74 | 32.04 | 31.18 | 0.947 | 0.929 |

Figure 6: Quantitative evaluation on the DTU dataset. ***RF** → large Chamfer distances are due to floaters being difficult to filter with a naive density-based thresholding. Our method offers a good trade-off between mesh reconstruction and visual fidelity.

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