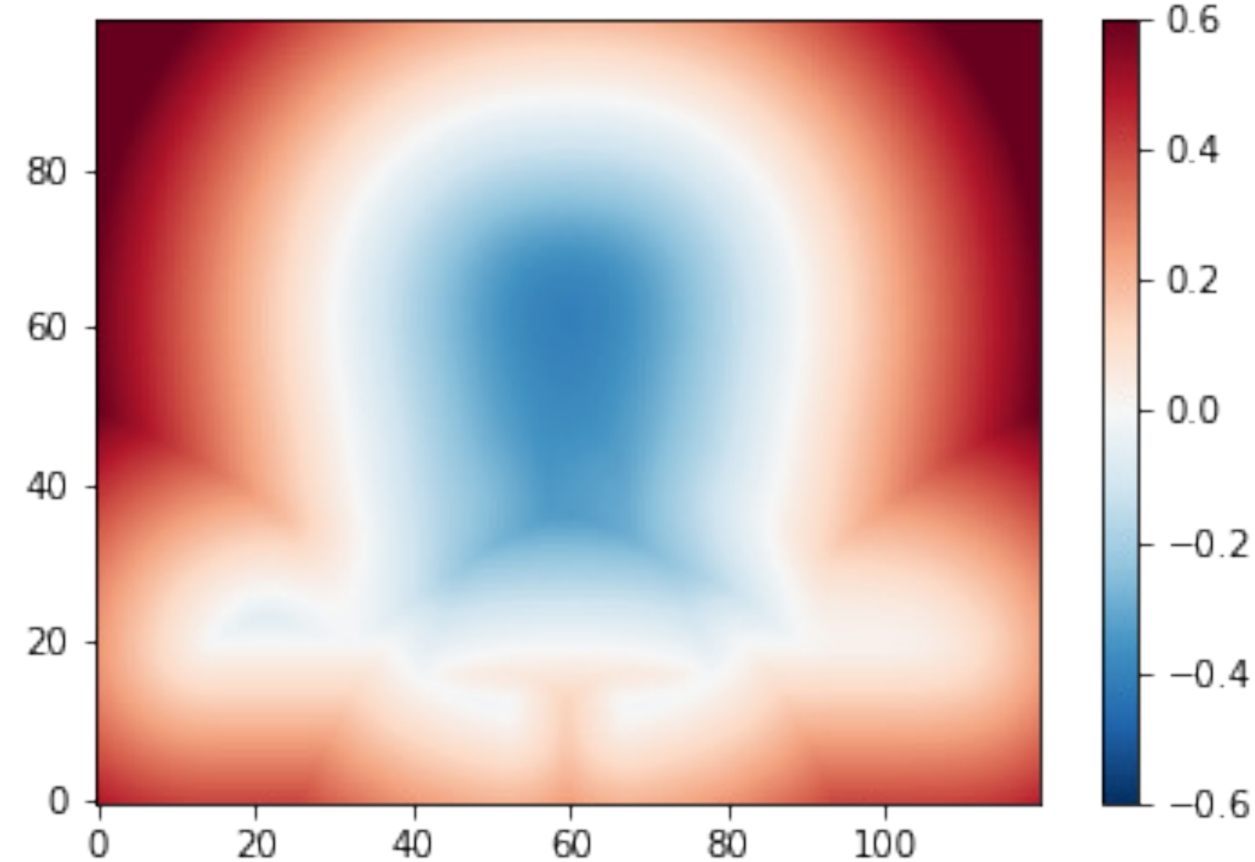
On the effectiveness of weight-encoded neural implicit 3D shapes

LIRIS - April/August 2022 - Nissim Maruani

Davies, T., Nowrouzezahrai, D., & Jacobson, A. (2020). *On the effectiveness of weight-encoded neural implicit 3D shapes*. arXiv preprint arXiv:2009.09808.

Background: SDF



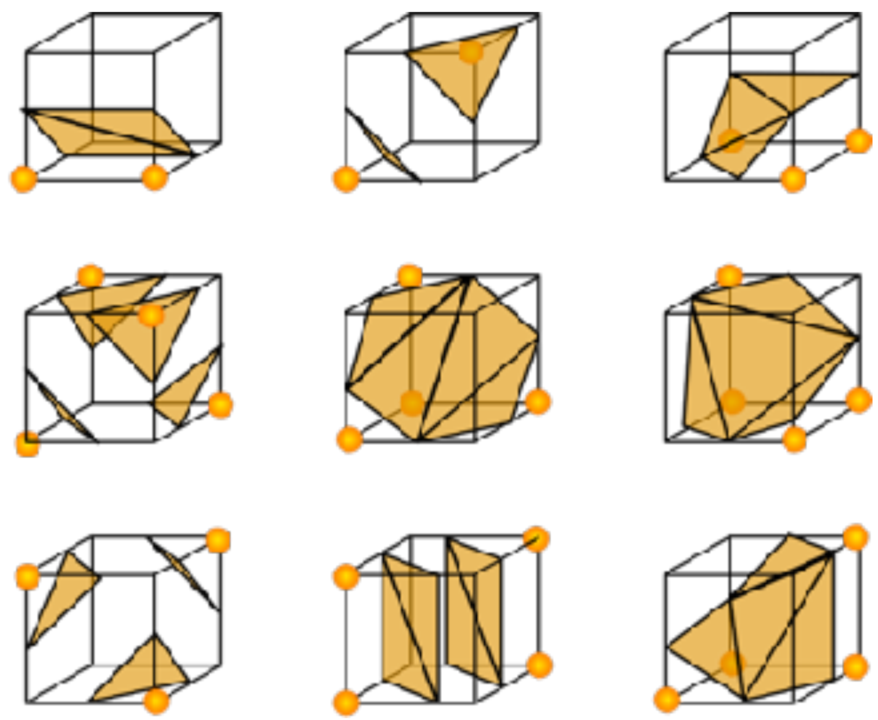
3D model

Signed Distance Function

Closed volume Ω

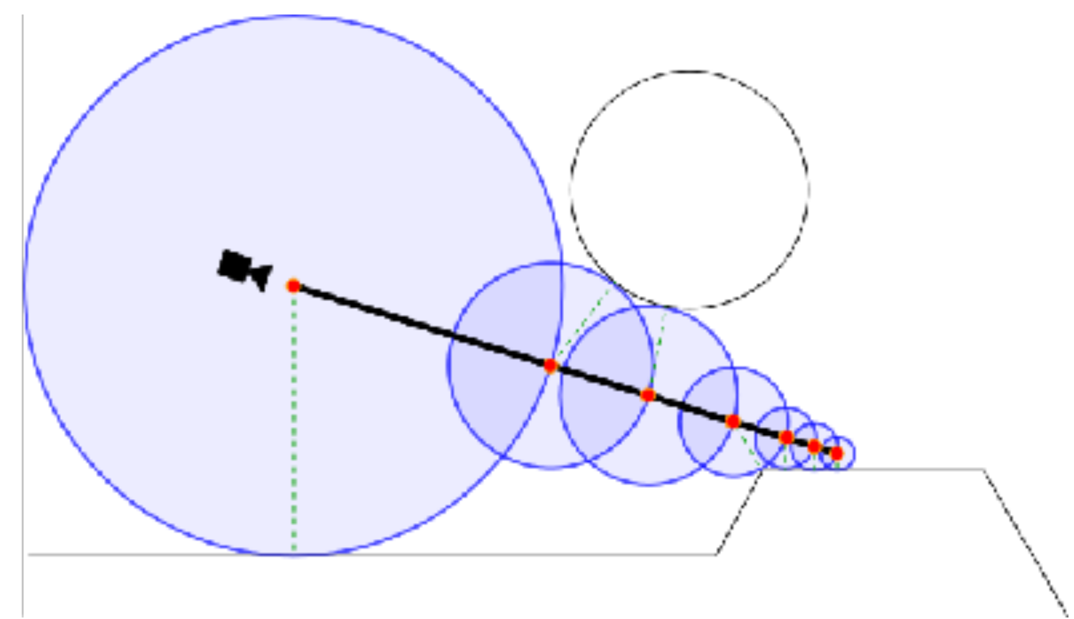
$$f : x \in \mathbb{R}^3 \mapsto (-1)^{1_{x \in \Omega}}\, d(x, \partial\Omega)$$

Background: SDF



Marching cubes

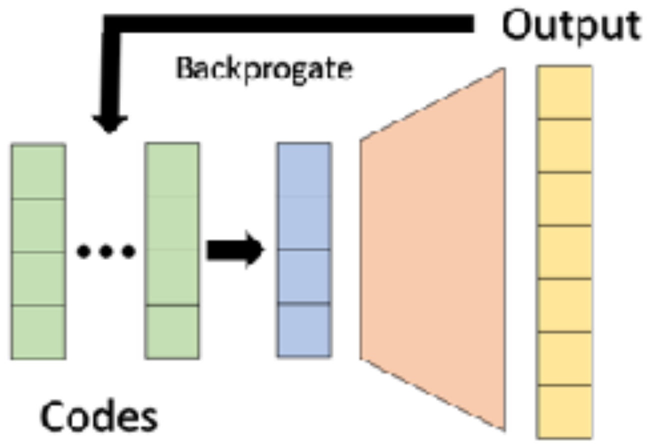
Surface extraction



Sphere tracing

Rendering

Background: DeepSDF



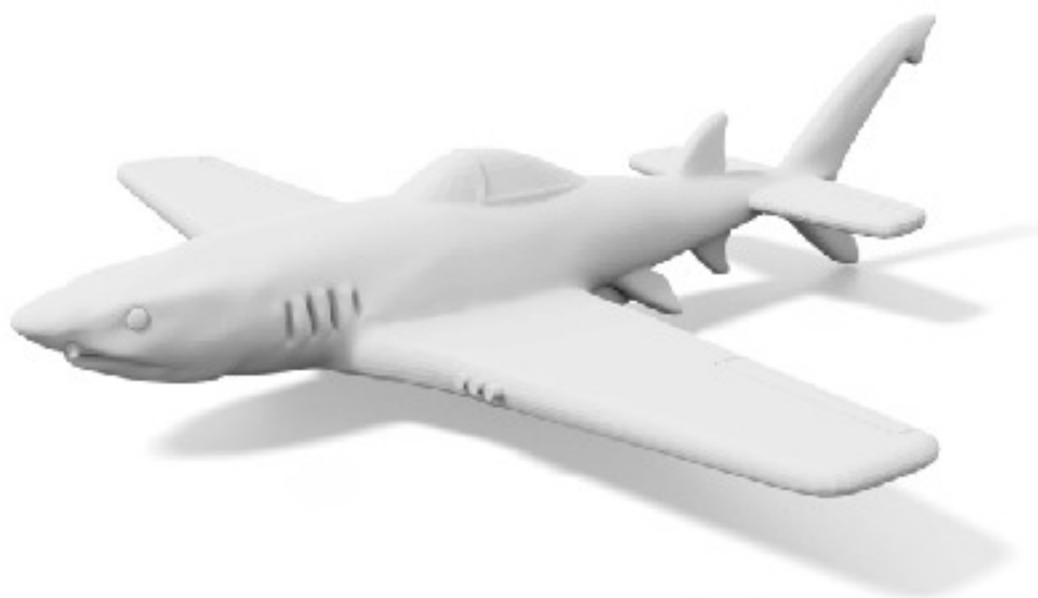
Network $f(x_i, z_i) = s_i$

Ground Truth Reconstruction

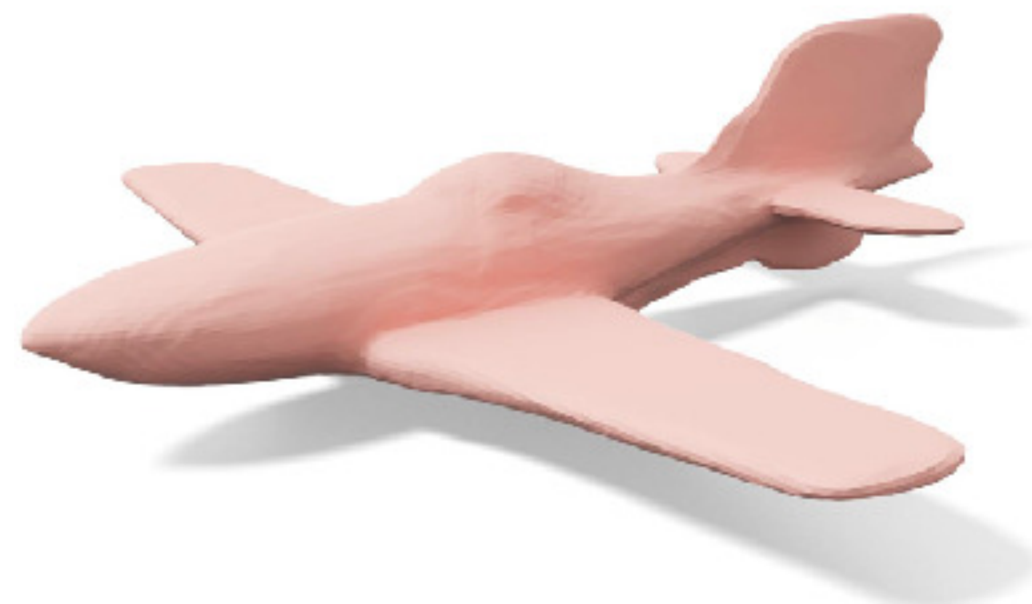
« Training a specific neural network for each shape is neither feasible nor very useful. »

Source [Park et al. 2019]

Weight-encoded neural implicit



Ground Truth



Deep SDF reconstruction

« We propose training a specific neural network for each shape and will show that this approach is both feasible and very useful. »

Source [Davies et al. 2020]

Weight-encoded neural implicit

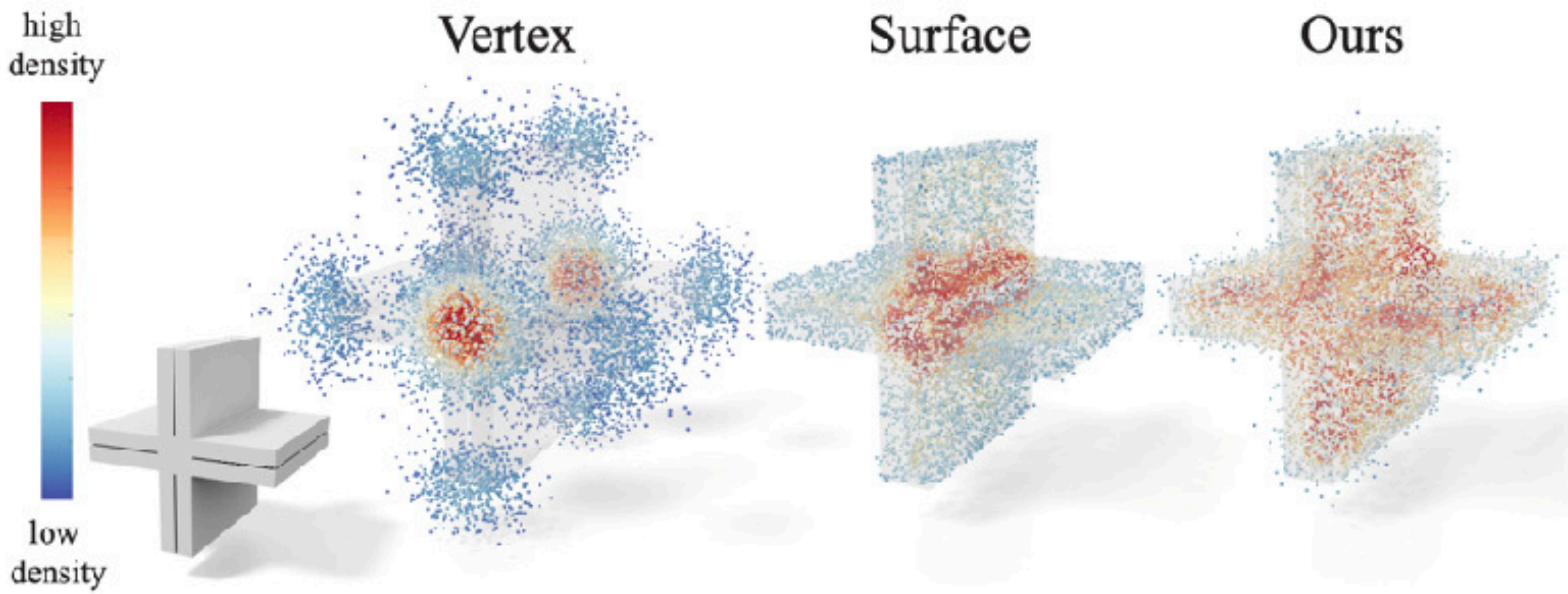
Training:

- Sample $N = 10^6$ points in the bounding volume
- Compute their true signed distance to the 3D closed mesh $g_S(x)$
- Train a neural network with the L_1 loss: $|f_\theta(x) - g_S(x)|$
- Store the weights θ

Inference:

- Load the estimated SDF f_θ
- Use it to render the shape (sphere tracing) or extract the surface (marching cubes)

Weight-encoded neural implicit

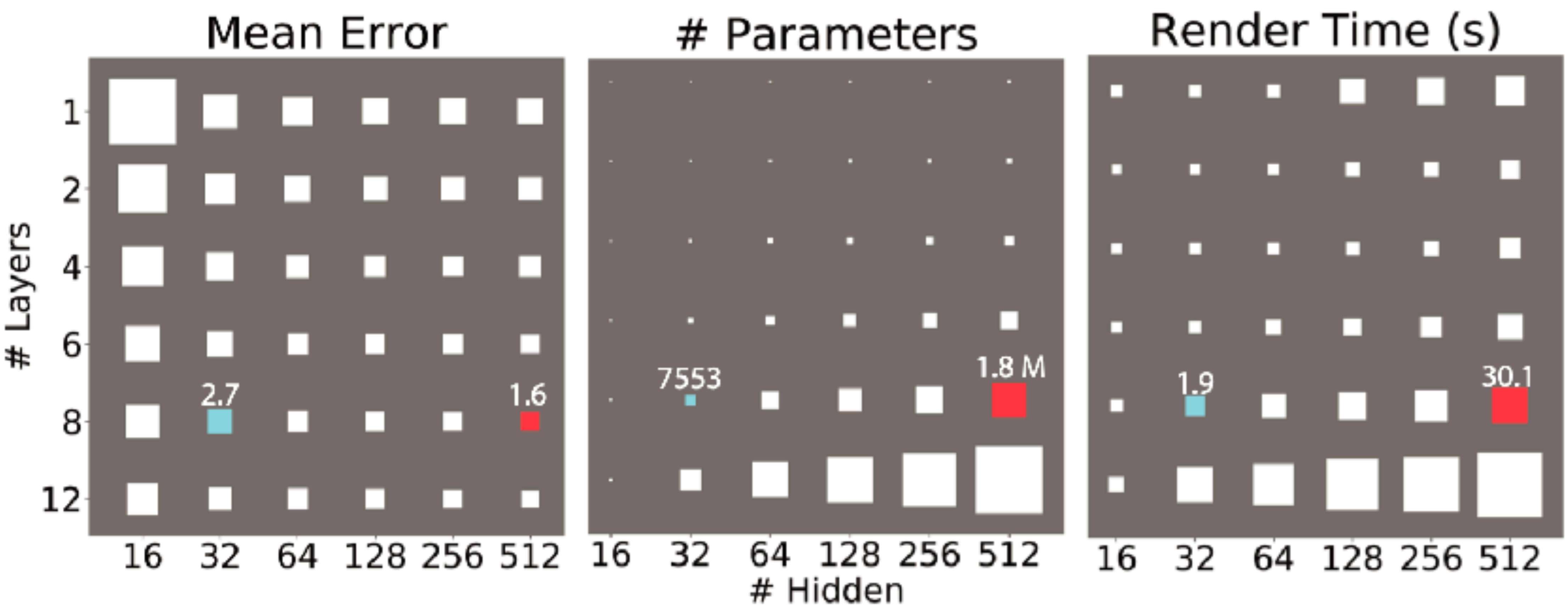


Sampling the SDF

Uniform samples, discard w.r.t. $1 - e^{-\beta |g_S(x)|}$

Source [Davies et al. 2020]

Weight-encoded neural implicit



Network architecture

7553 parameters: 8 layers, 32 features
59 kB

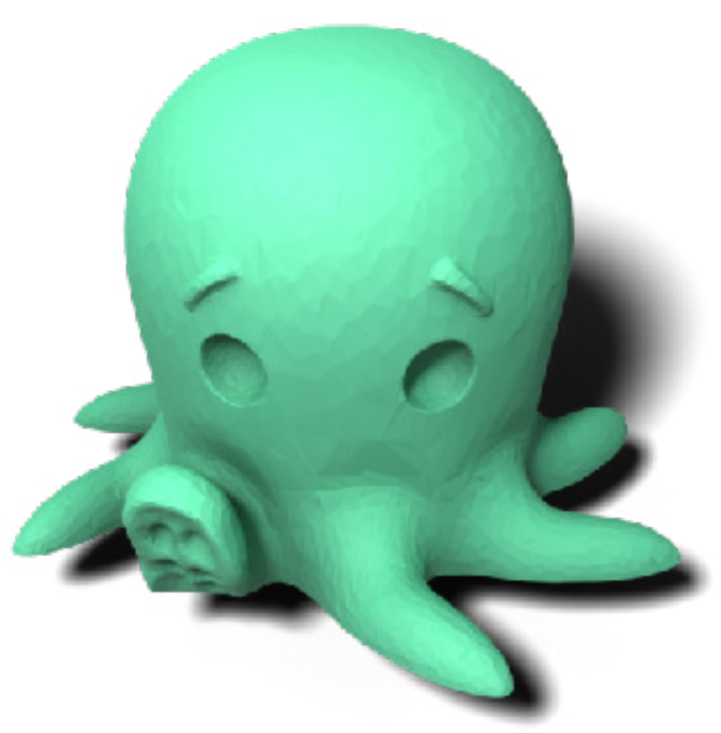
Source [Davies et al. 2020]

Weight-encoded neural implicit

Ground Truth   Neural Implicit   Quadric Error Metric

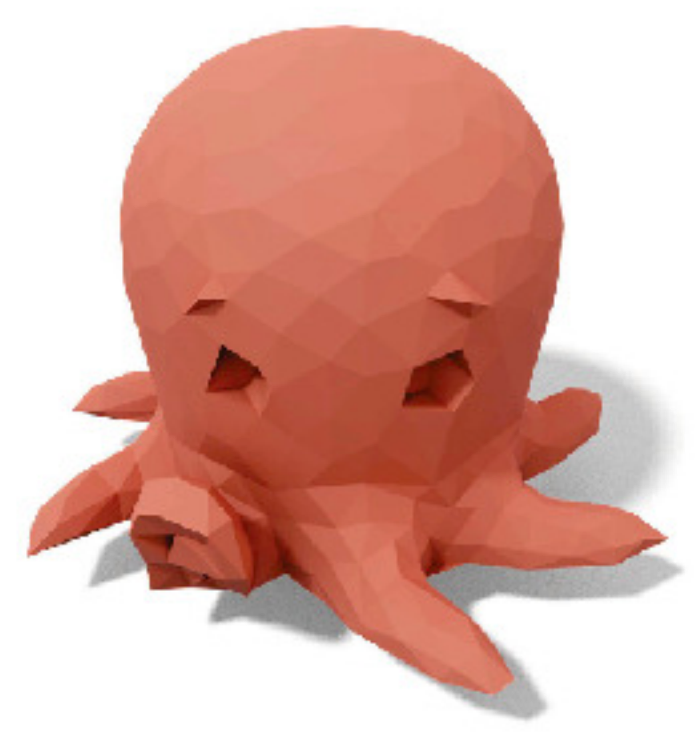
Sources [Davies et al. 2020] [Garland et al. 1997]

Weight-encoded neural implicit



Ground Truth

Neural Implicit



Quadric Error Metric

Sources [Davies et al. 2020] [Garland et al. 1997]

Conclusion

Compact representation:

- 59 kB (66x size reduction)
- Relatively quick training (1 m) and inference time (1.9 s)
- Compared to classical approaches: no limits on the resolution

Drawbacks:

- Heavy sampling
- Loss of details

References

[Davies et al. 2019] Davies, T., Nowrouzezahrai, D., & Jacobson, A. (2020). *On the effectiveness of weight-encoded neural implicit 3D shapes*. arXiv preprint arXiv:2009.09808.

[Garland et al. 1997] Garland, M., & Heckbert, P. S. (1997, August). *Surface simplification using quadric error metrics.* In Proceedings of the 24th annual conference on Computer graphics and interactive techniques (pp. 209-216).

[Park et al. 2019] Park, J. J., Florence, P., Straub, J., Newcombe, R., & Lovegrove, S. (2019). *Deepsdf: Learning continuous signed distance functions for shape representation.* In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 165-174).