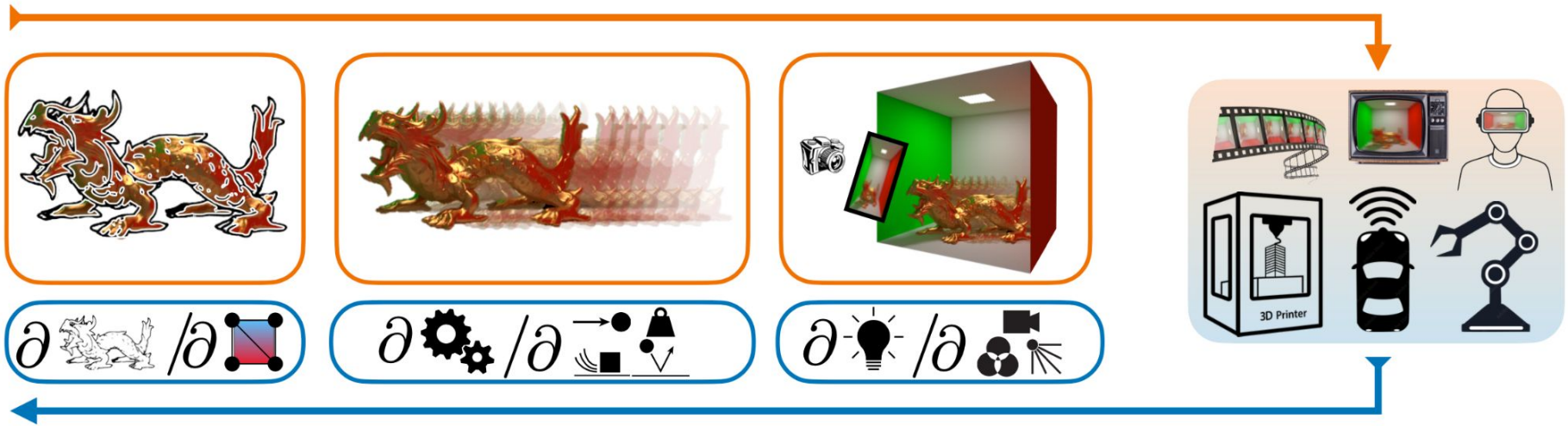
# Differentiable Methods for Visual Computing

Dr Fangcheng Zhong

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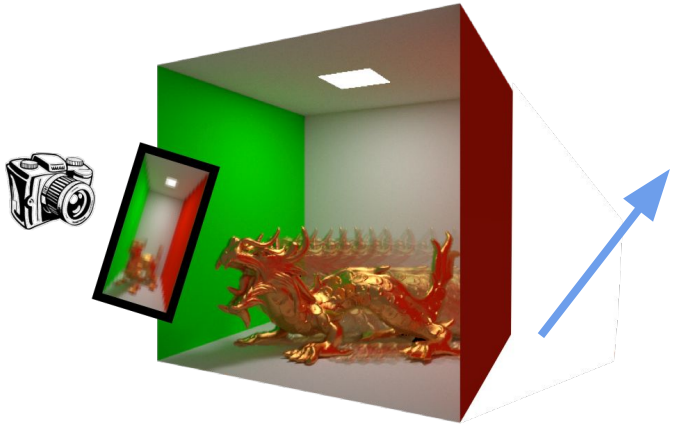
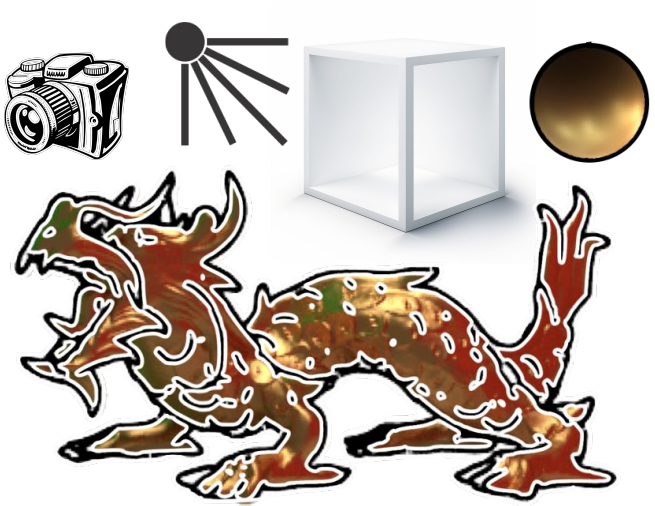
# Inverse Problems in Machine Perception

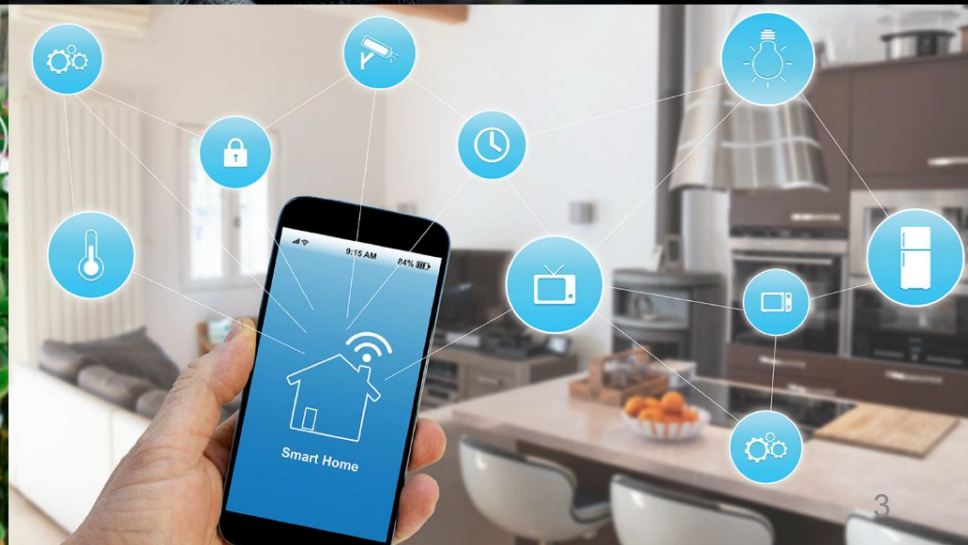
**Observation**
**(*e.g.* images, Lidar, *etc.*)**





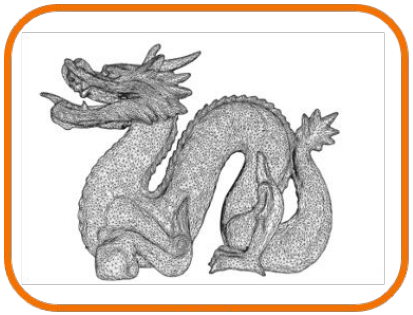
**Causal factors**
**(camera and scene parameters,**
***e.g.* geometry, lighting,**
**materials, motion, *etc.*)**


Self
Driving


9:15 AM
24%
Smart Home

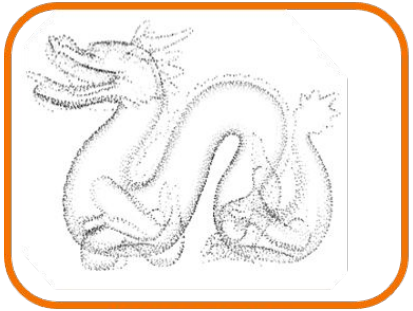
# Geometry Representations

## Surface Representations



Mesh

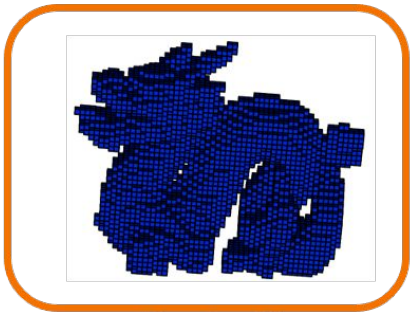

Parametric surface



Point clouds

Signed distance function

## Volume Representations

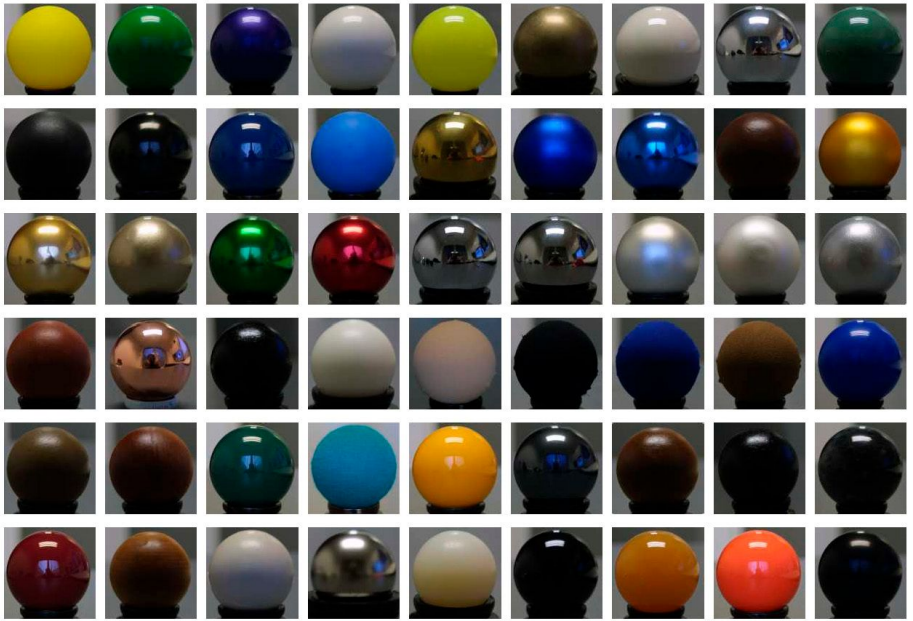


Voxel grids

Density fields

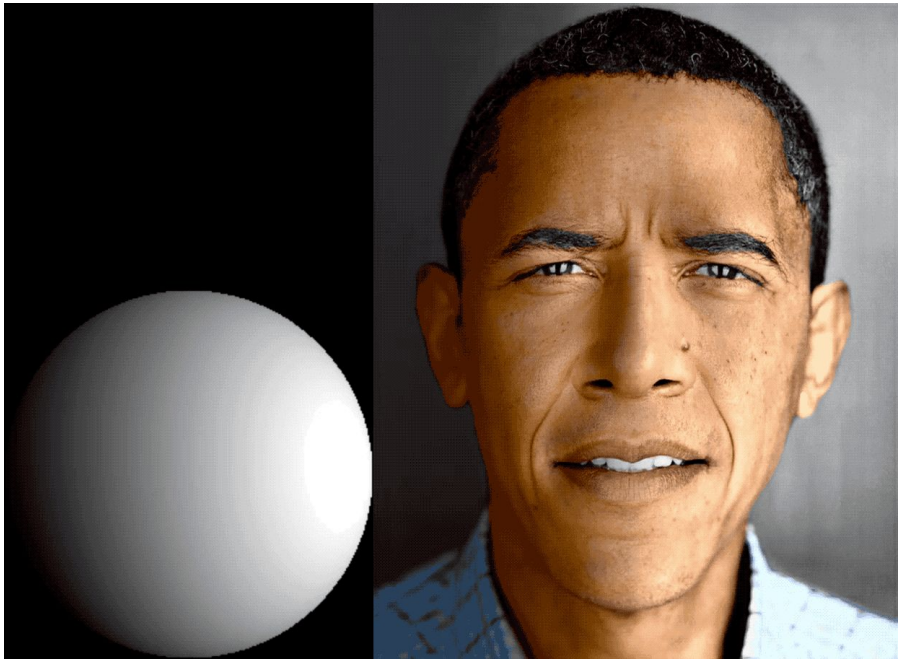
# Material Representations

Textures

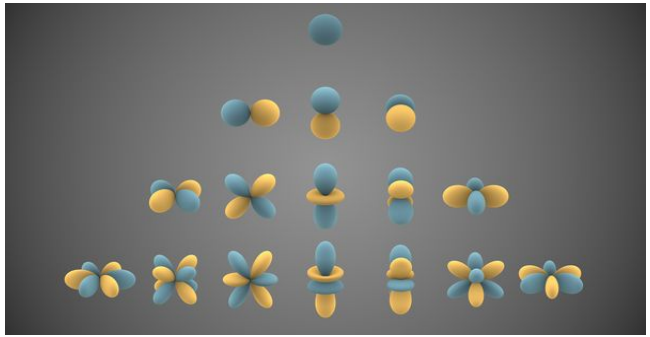


BRDFs

# Light Representations

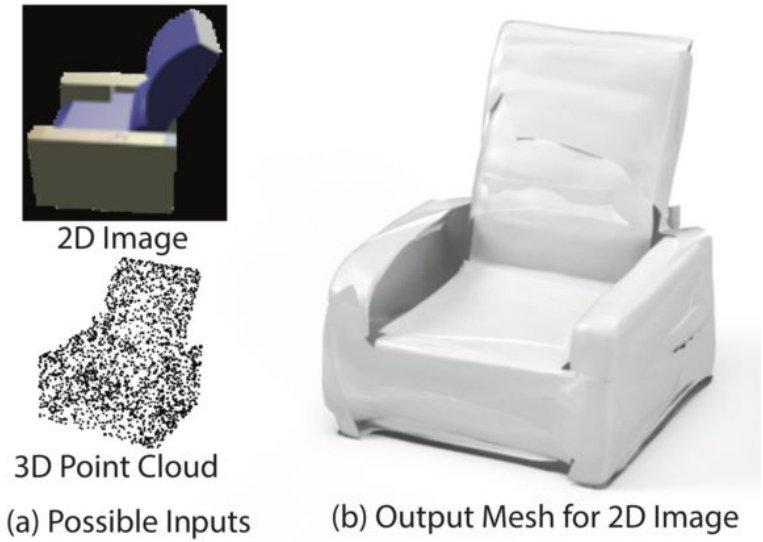


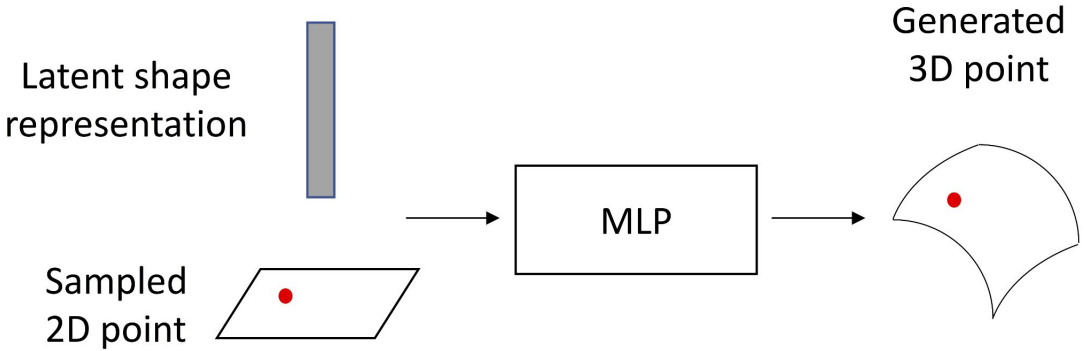
Lightmap Images



Spherical harmonics

# Data-Driven Inference

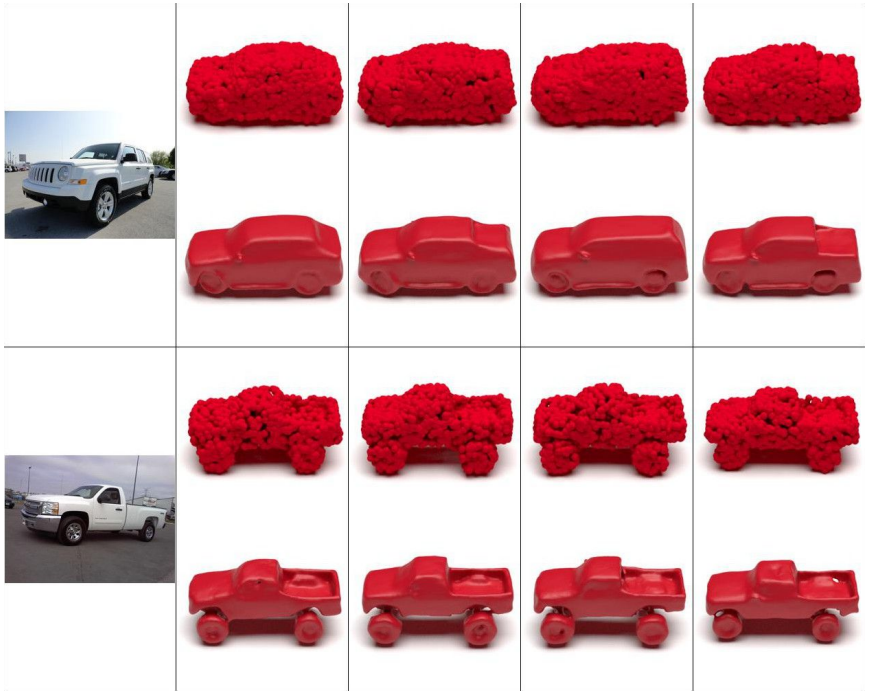


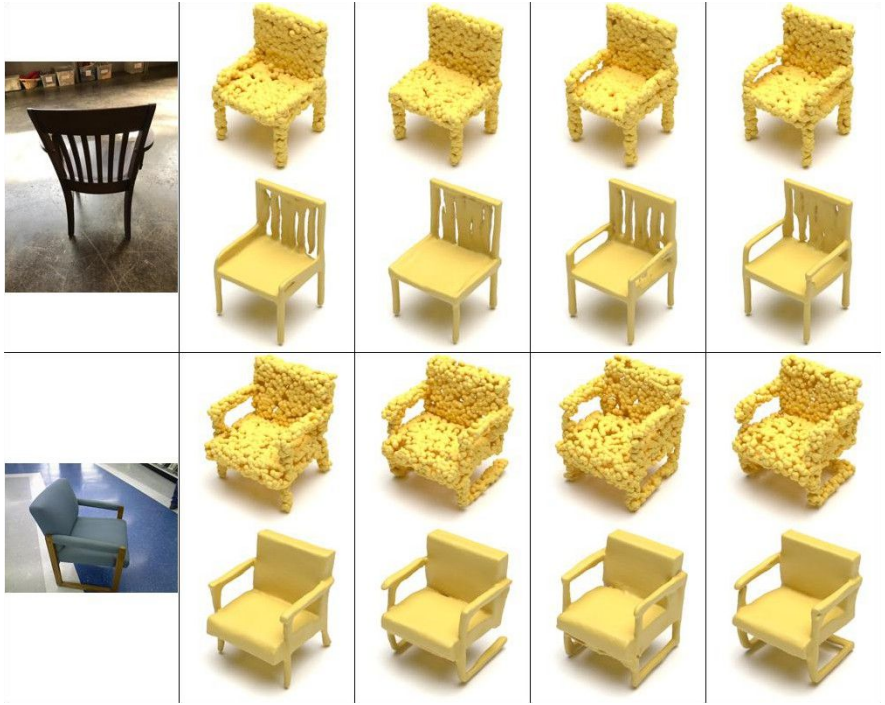






Groueix, Thibault, Matthew Fisher, Vladimir G. Kim, Bryan C. Russell, and Mathieu Aubry. "A papier-mâché approach to learning 3d surface generation." CVPR 2018

# Generative Methods



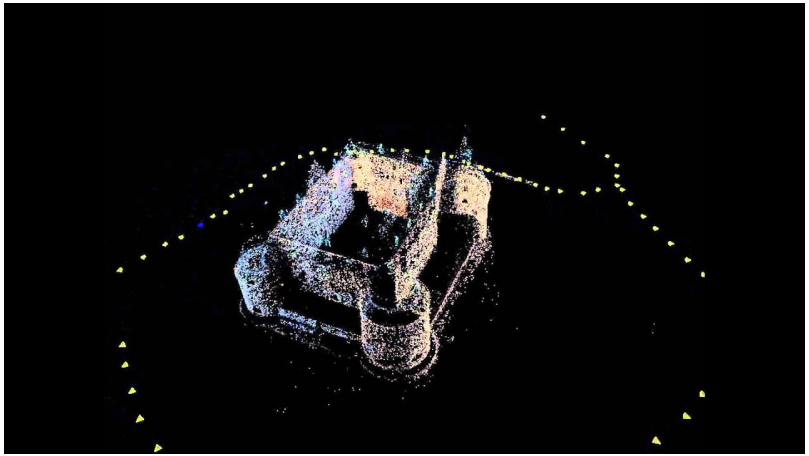


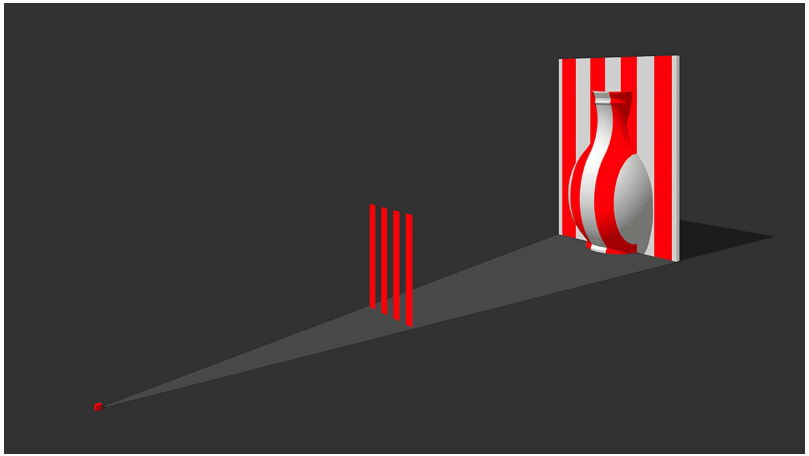


Zeng, Xiaohui, Arash Vahdat, Francis Williams, Zan Gojcic, Or Litany, Sanja Fidler, and Karsten Kreis. "LION: Latent point diffusion models for 3D shape generation." NeurIPS 2022

# Traditional CV Methods

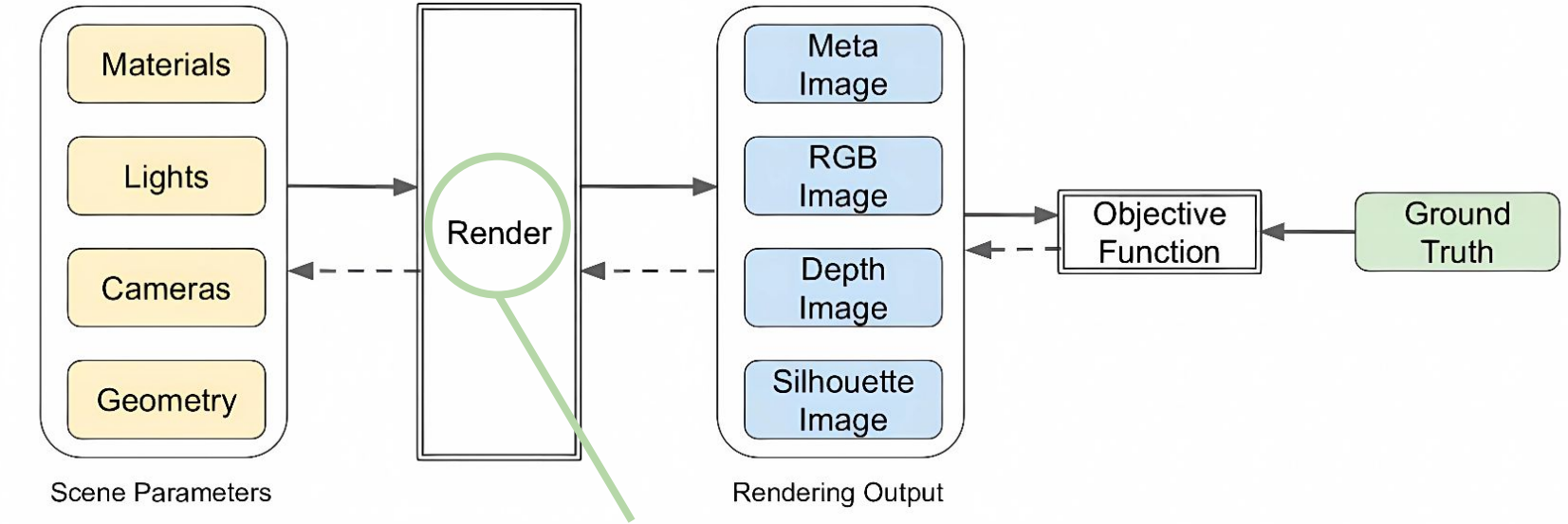
- Constrained optimization
  - SLAM, Structure from Motion
  - Light probes, structured light





# Differentiable Rendering

Generalization of traditional CV methods



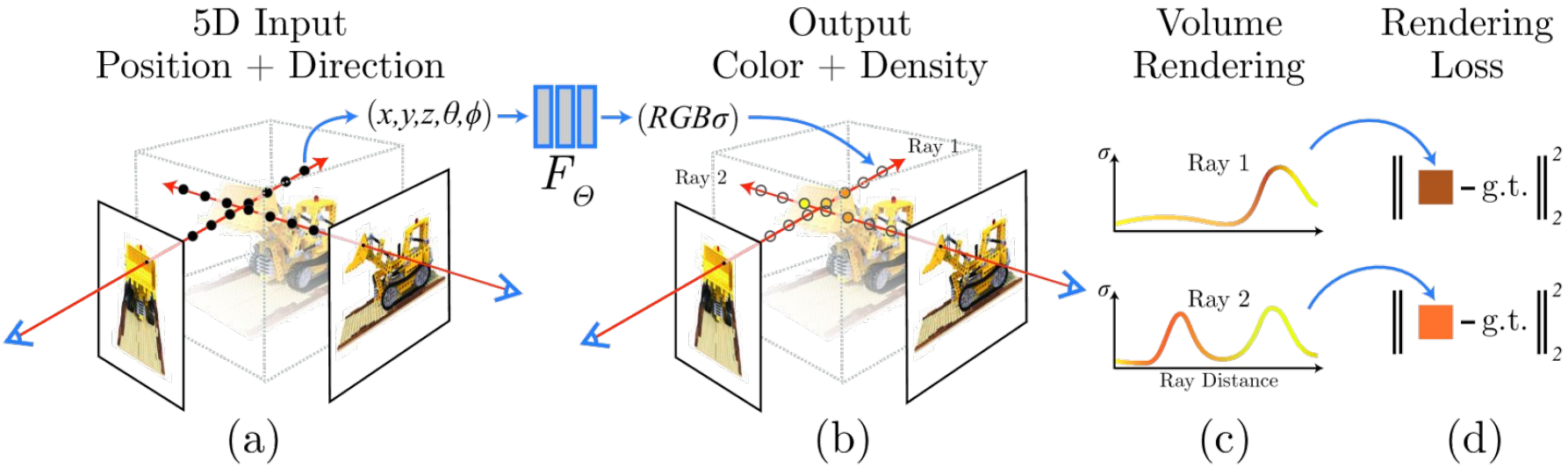

Derive useful gradients in rendering

# Differentiable Volume Rendering



Ben Mildenhall, Pratul P. Srinivasan, Matthew Tancik, Jonathan T. Barron, Ravi Ramamoorthi, and Ren Ng. Nerf: Representing scenes as neural radiance fields for view synthesis. In ECCV, 2020

# Differentiable Volume Rendering



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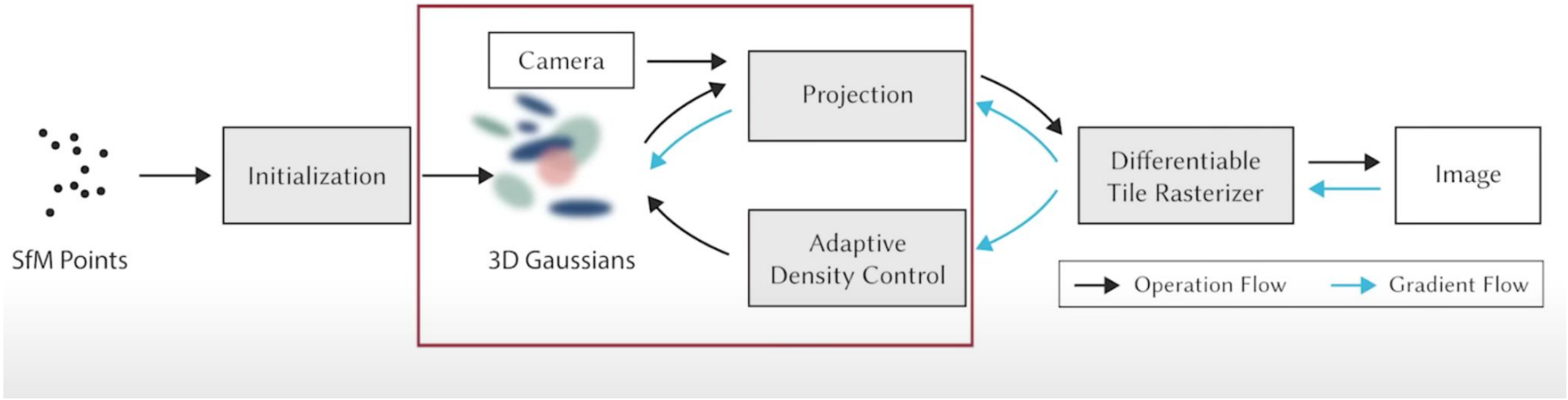




Kerbl, B., Kopanas, G., Leimkühler, T., & Drettakis, G. (2023). 3d gaussian splatting for real-time radiance field rendering. *ACM Transactions on Graphics (ToG)*, *42*(4), 1-14

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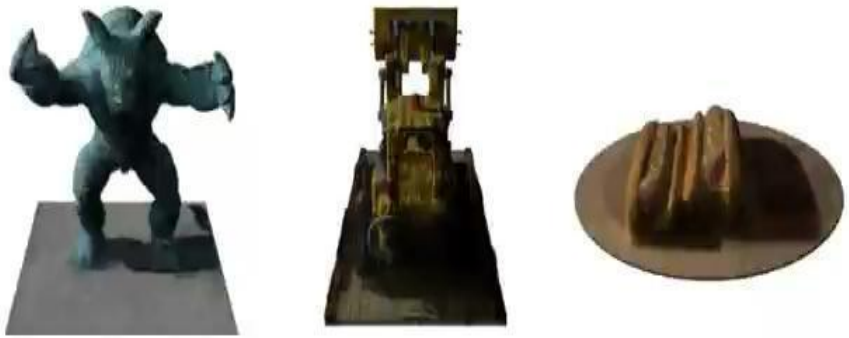




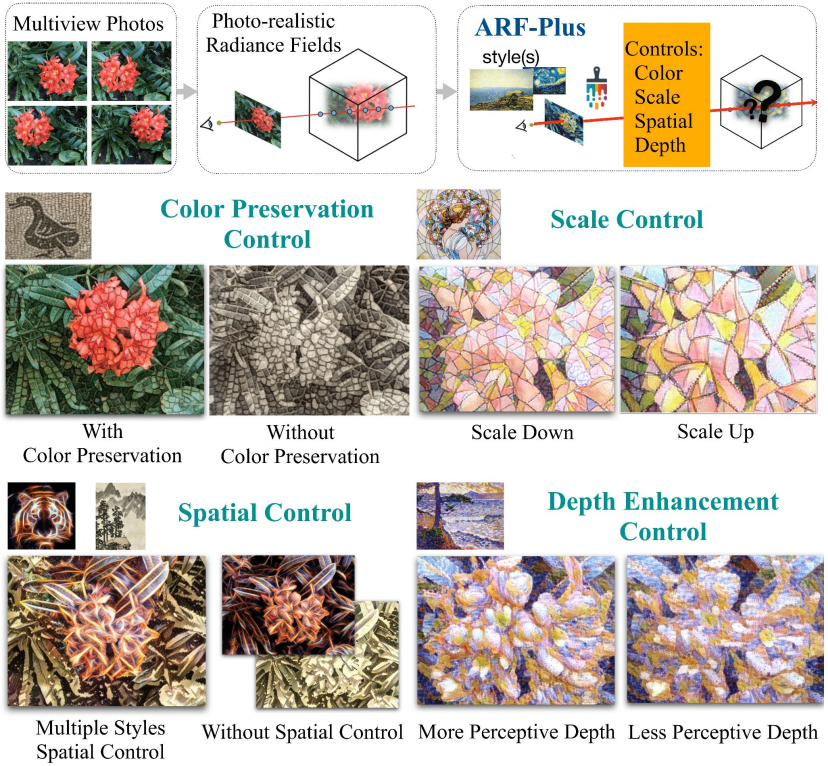
Srinivasan, P.P., Deng, B., Zhang, X., Tancik, M., Mildenhall, B. and Barron, J.T. Nerv: Neural reflectance and visibility fields for relighting and view synthesis. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* 2021 (pp. 7495-7504).

# Differentiable Volume Rendering




Tianhao Wu, Fangcheng Zhong, Andrea Tagliasacchi, Forrester Cole, and Cengiz Oztireli. D2NeRF: Self-Supervised Decoupling of Dynamic and Static Objects from a Monocular Video. In NeurIPS, 2022

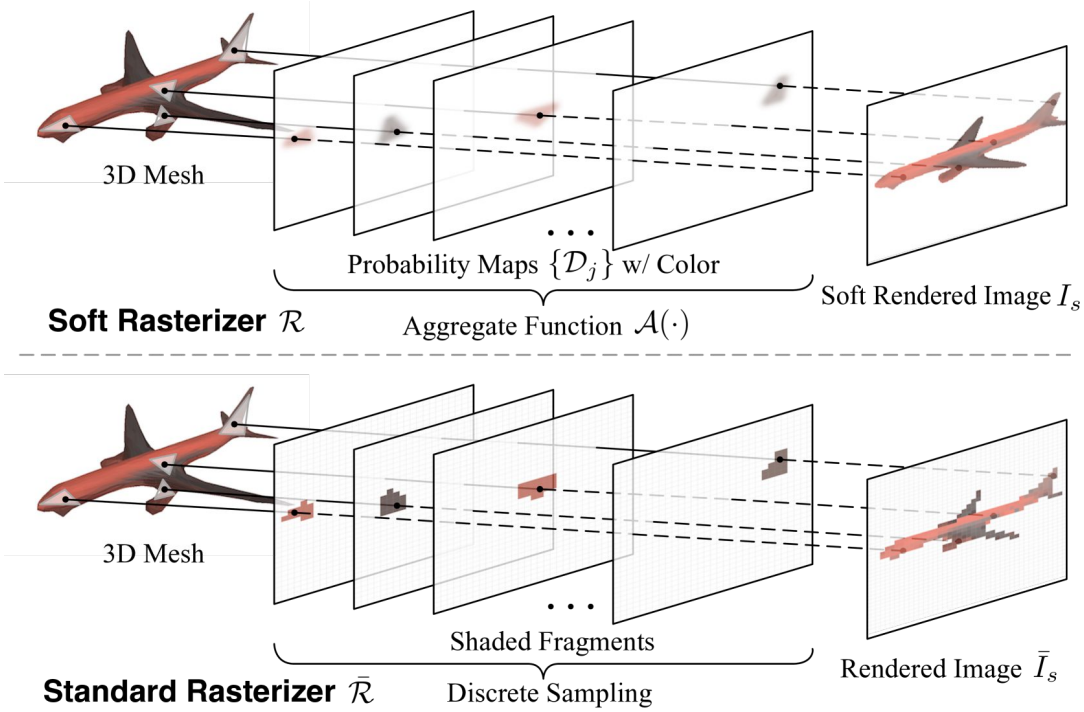
# Differentiable Volume Rendering






Li, Wenzhao, Tianhao Wu, Fangcheng Zhong, and Cengiz Oztireli. "ARF-Plus: Controlling Perceptual Factors in Artistic Radiance Fields for 3D Scene Stylization." *arXiv preprint arXiv:2308.12452* (2023).

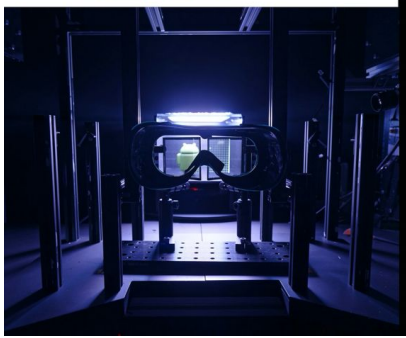
# Differentiable Surface Rendering

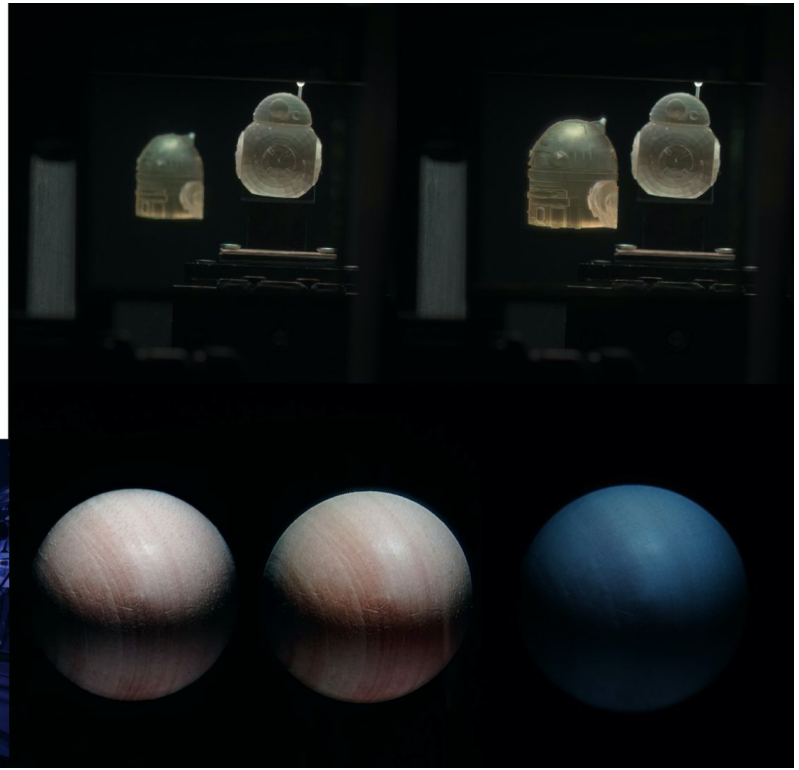





Liu, Shichen, Tianye Li, Weikai Chen, and Hao Li. "Soft rasterizer: A differentiable renderer for image-based 3d reasoning." In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 7708-7717. 2019.

# Differentiable Surface Rendering





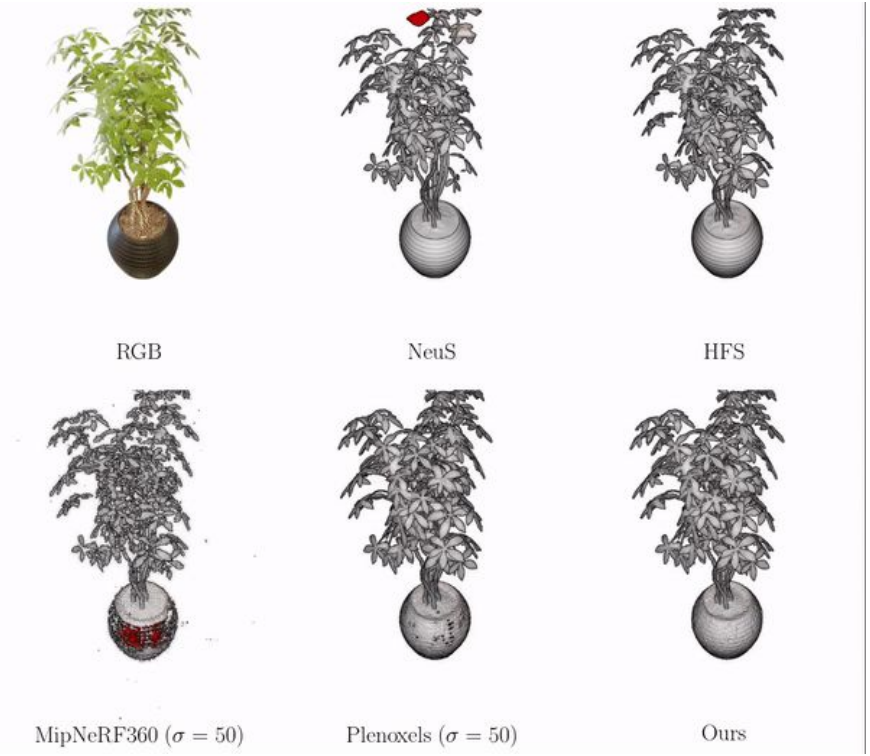
Fangcheng Zhong, Akshay Jindal, Ali Özgür Yöntem, Param Hanji, Simon J. Watt, and Rafał K. Mantiuk. 2021. Reproducing Reality with a High-Dynamic-Range Multi-Focal Stereo Display. ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH Asia, Journal Track), 2021

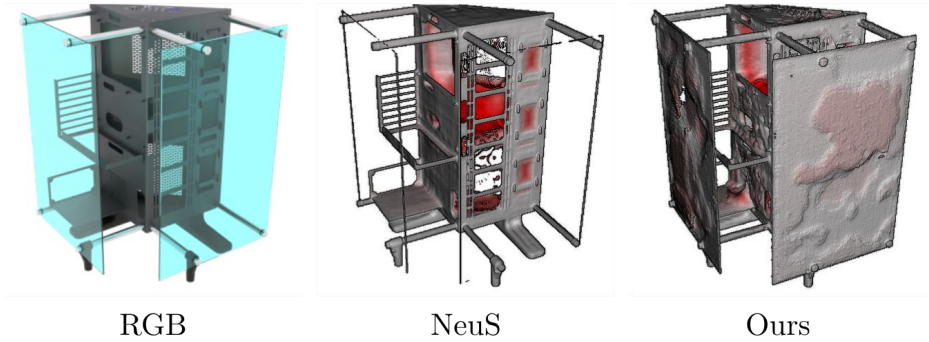
# Differentiable Surface Rendering




Loubet, Guillaume, Nicolas Holzschuch, and Wenzel Jakob. "Reparameterizing discontinuous integrands for differentiable rendering." *ACM Transactions on Graphics (TOG)* 38.6 (2019): 1-14.

# Differentiable Surface Rendering

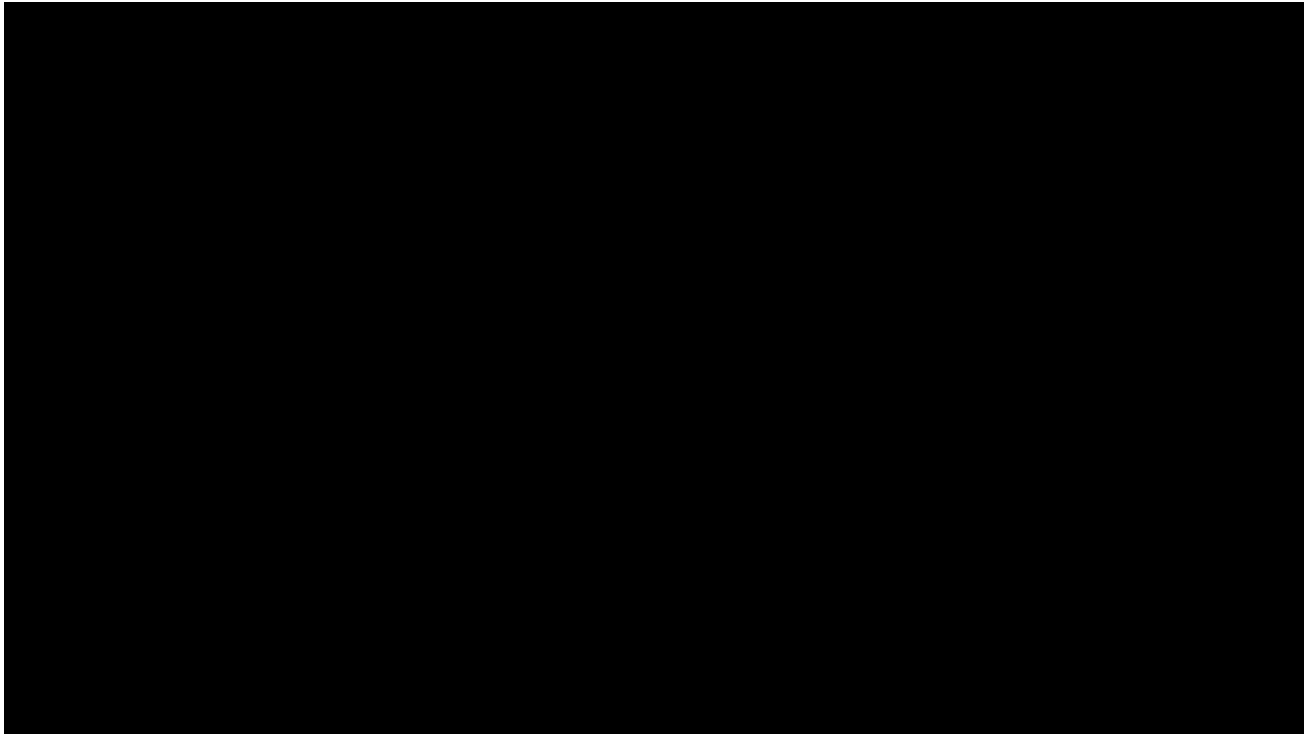





Wu, Tianhao, Hanxue Liang, Fangcheng Zhong, Gernot Riegler, Shimon Vainer, and Cengiz Oztireli. "alpha Surf: Implicit Surface Reconstruction for Semi-Transparent and Thin Objects with Decoupled Geometry and Opacity." *arXiv preprint 2023*

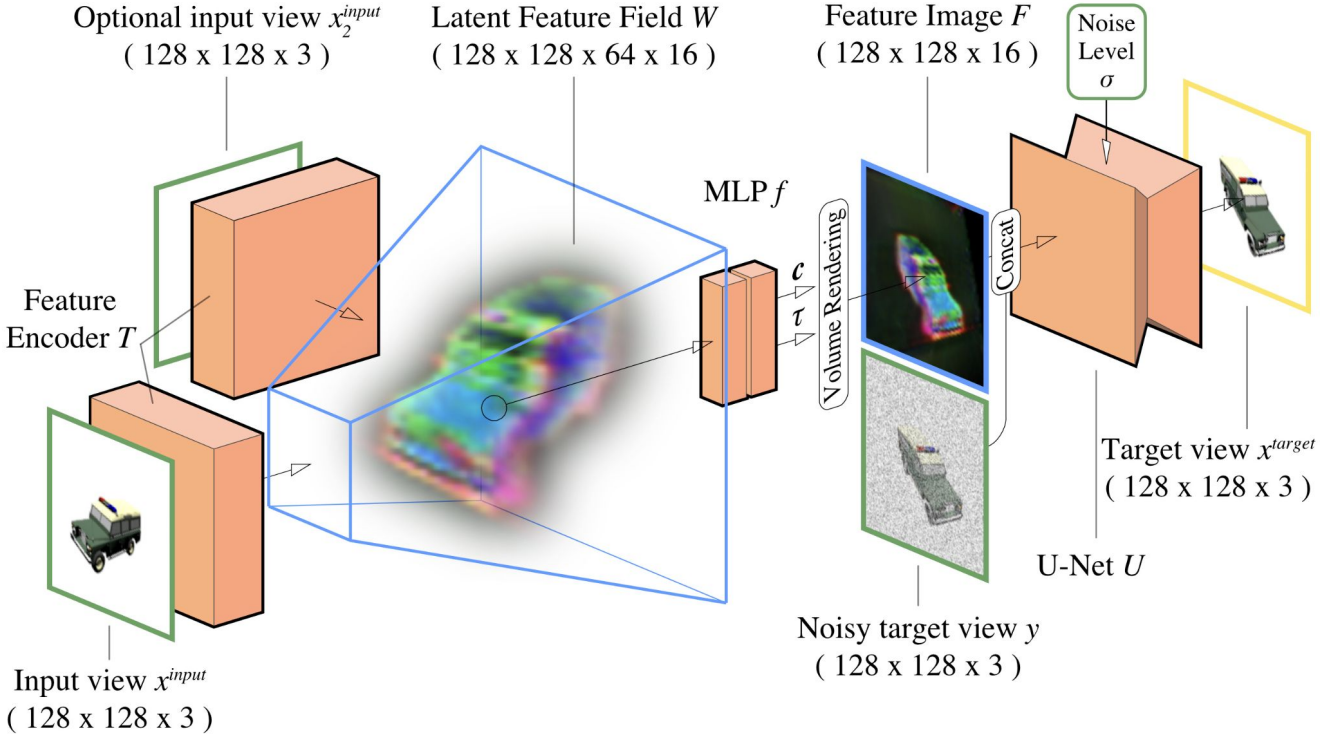
# Hybrid Representations for Differentiable Rendering





Sitzmann, Vincent, Semon Rezchikov, Bill Freeman, Josh Tenenbaum, and Fredo Durand. "Light field networks: Neural scene representations with single-evaluation rendering." NeurIPS 2021

# Differentiable Rendering with Data-Driven Prior

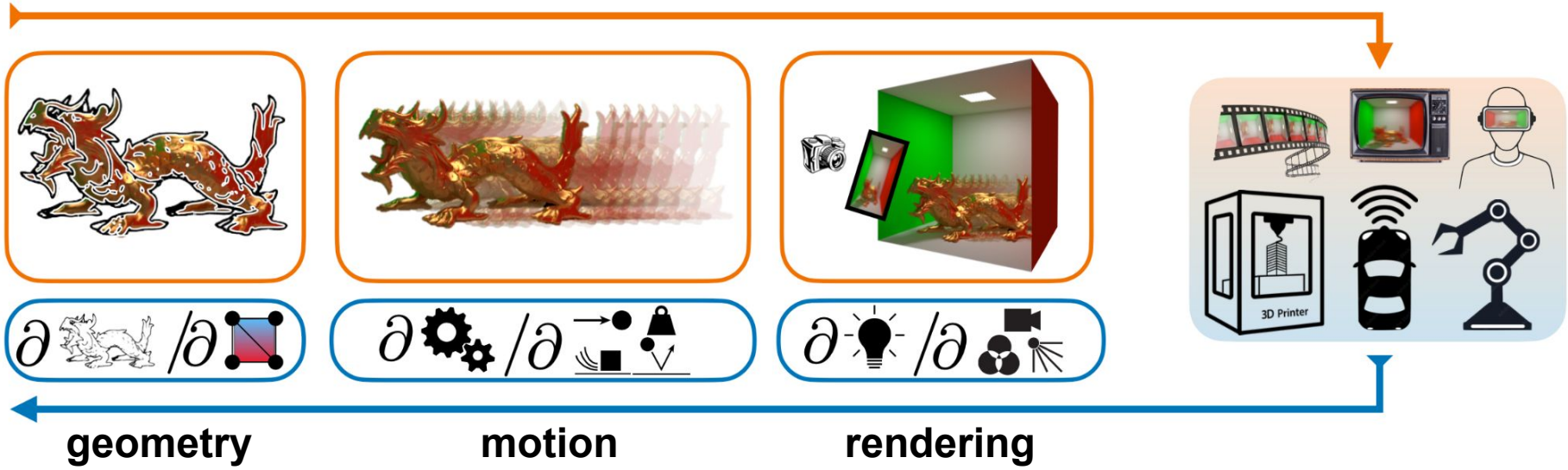





Chan, E. R., Nagano, K., Chan, M. A., Bergman, A. W., Park, J. J., Levy, A., ... & Wetzstein, G. (2023). GeNVS: Generative novel view synthesis with 3D-aware diffusion models.

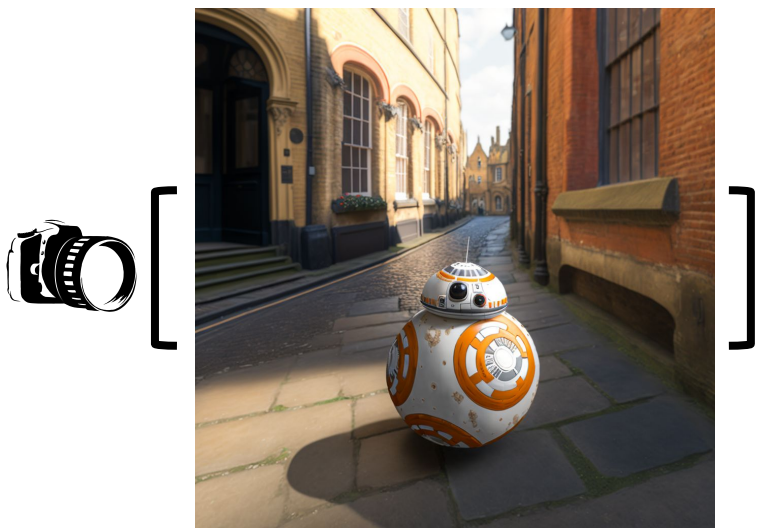
# Extended Differentiable Visual Computing

Everything differentiable can be integrated!



# Extended Differentiable Visual Computing

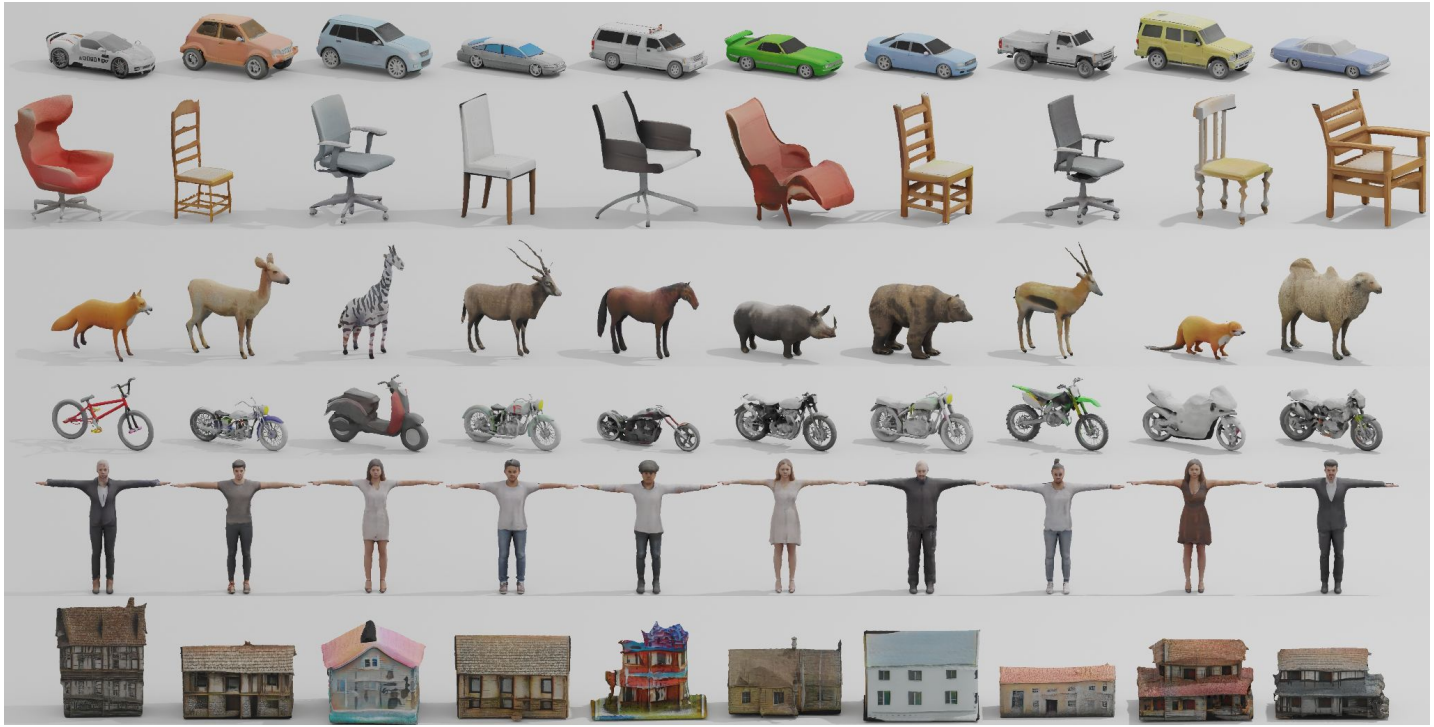
real



display

Differentiable displays and cameras

# Differentiable Visual Computing for Generative AI



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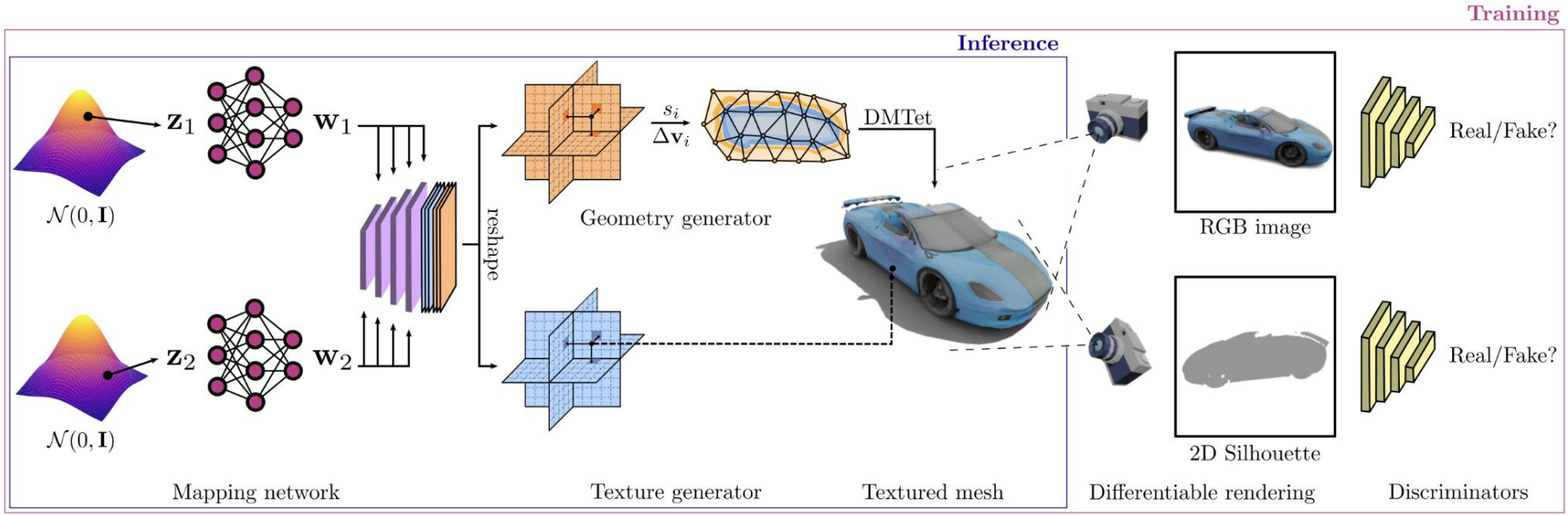
Gao, Jun, Tianchang Shen, Zian Wang, Wenzheng Chen, Kangxue Yin, Daiqing Li, Or Litany, Zan Gojcic, and Sanja Fidler. "GET3D: A Generative Model of High Quality 3D Textured Shapes Learned from Images." *In NeurIPS, 2022*

# Differentiable Visual Computing for Generative AI



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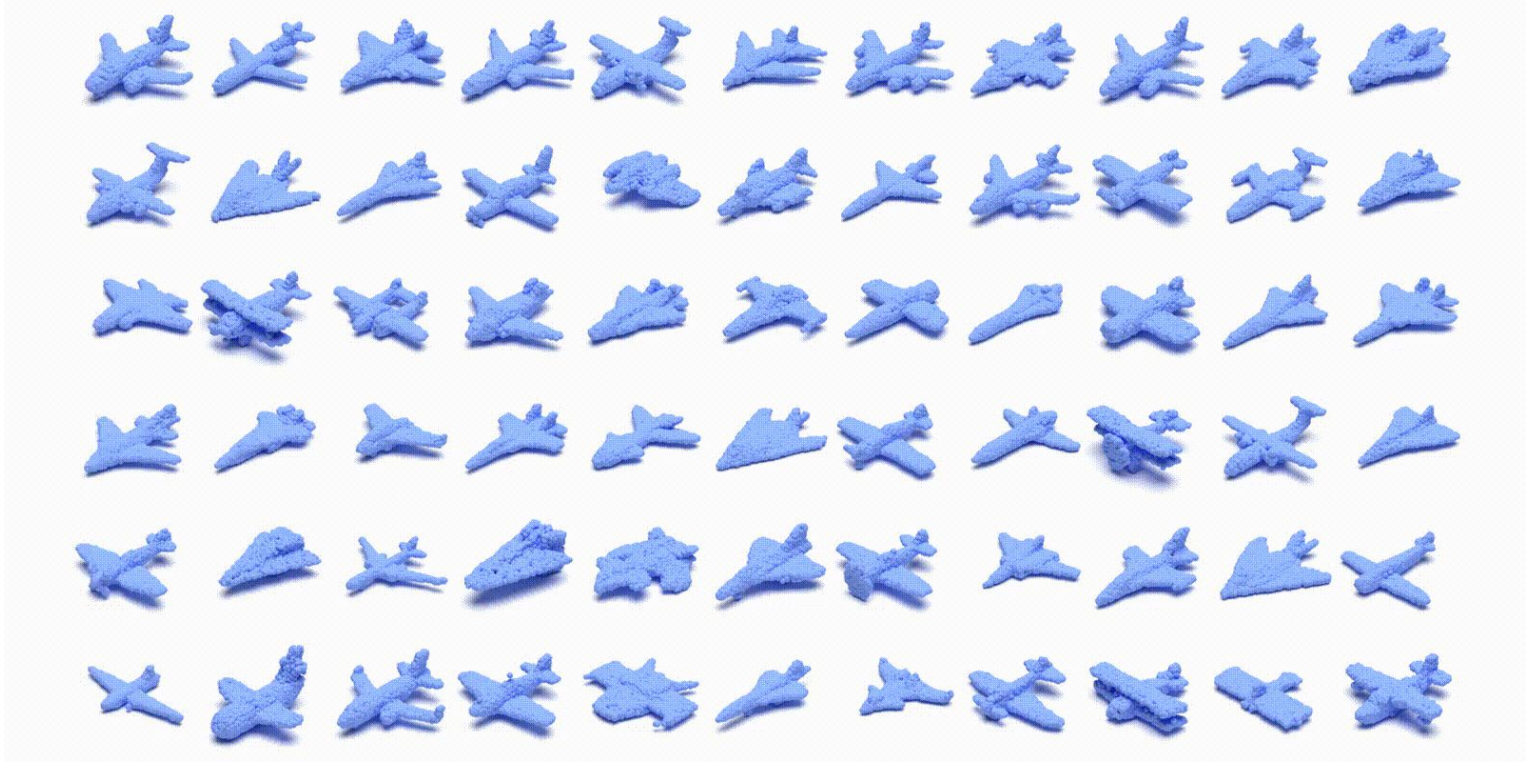



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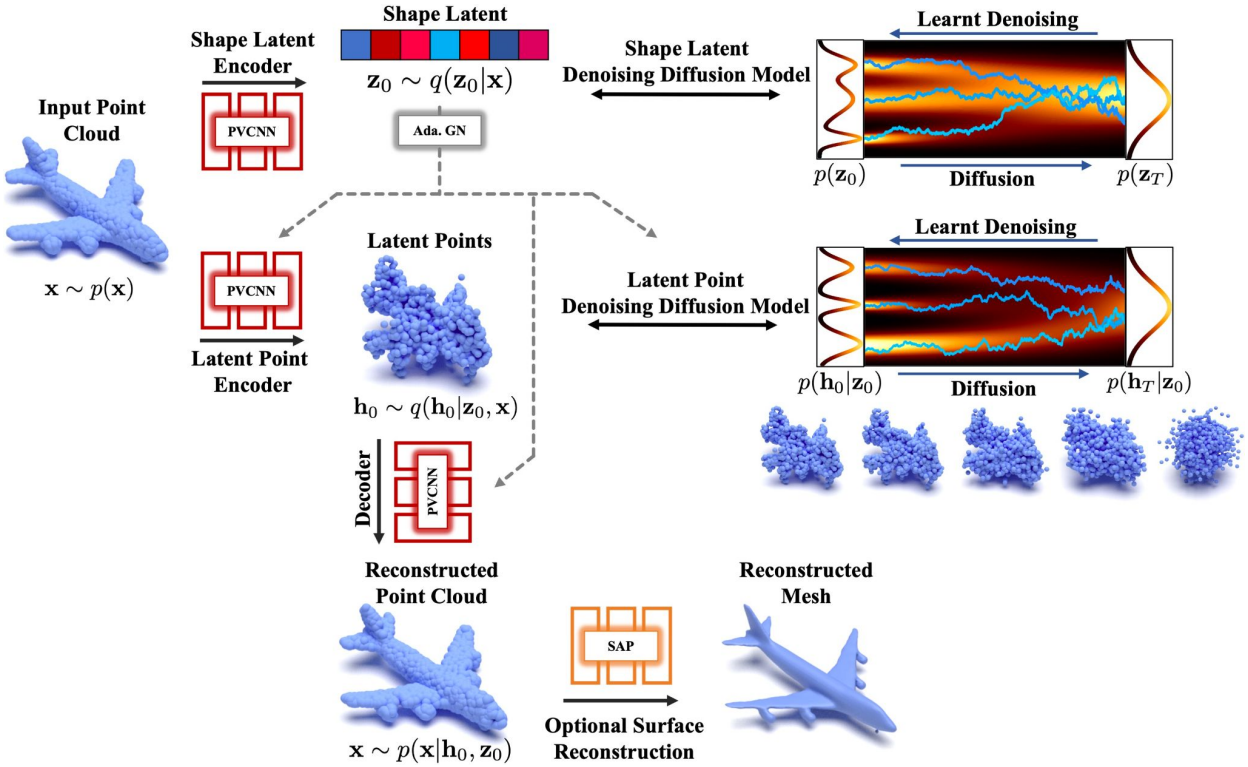




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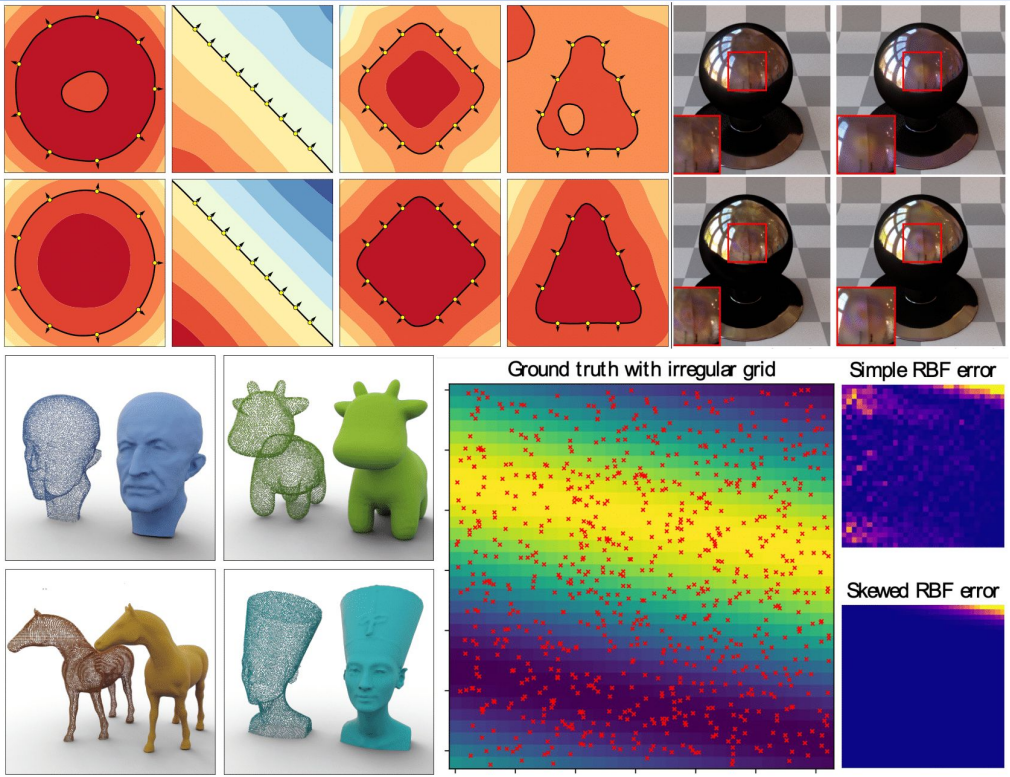
# Constrained Neural Fields for Differentiable Visual Computing






Fangcheng Zhong, Kyle Fogarty, Param Hanji, Tianhao Wu, Alejandro Sztraj- man, Andrew Spielberg, Andrea Tagliasacchi, Petra Bosilj, and Cengiz Oztireli. Neural fields with hard constraints of arbitrary differential order. *NeurIPS, 2023*

# Summary

- Differentiable visual computing for inverse problems
- Differentiable visual computing for machine learning
- Basics concepts, applications, research topics