Thermoxels

A voxel-based method to generate simulation-ready 3D thermal models

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Background

Building (energy consumption) statistics

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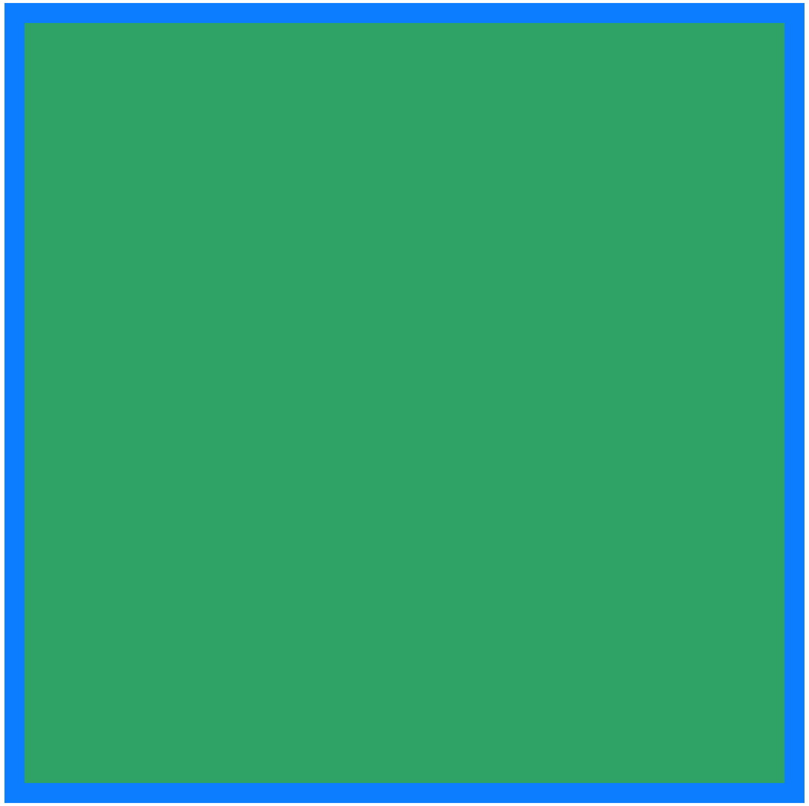
- 85 to 95% still standing by 2050



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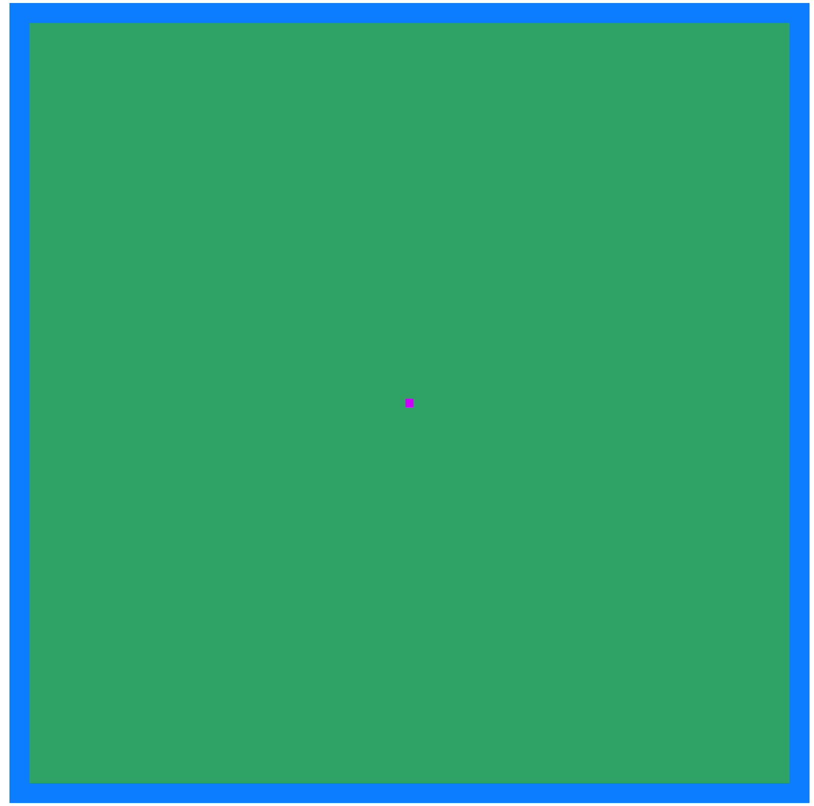
- Weighted annual energy renovation rate: 1%



Building (energy consumption) statistics

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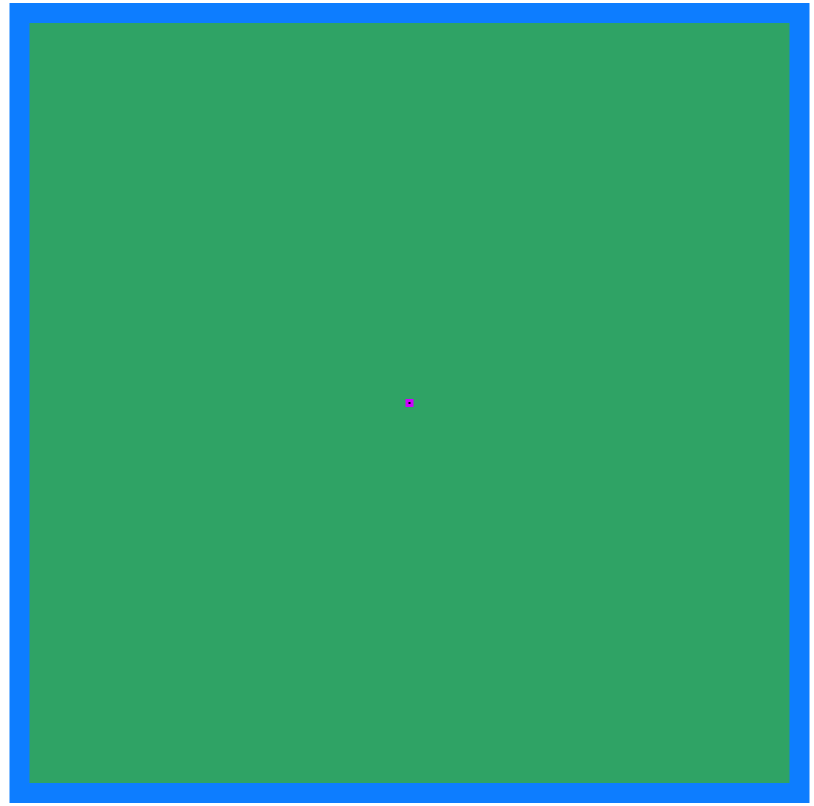
- Weighted annual energy renovation rate: 1%
- 0.2% deep renovation



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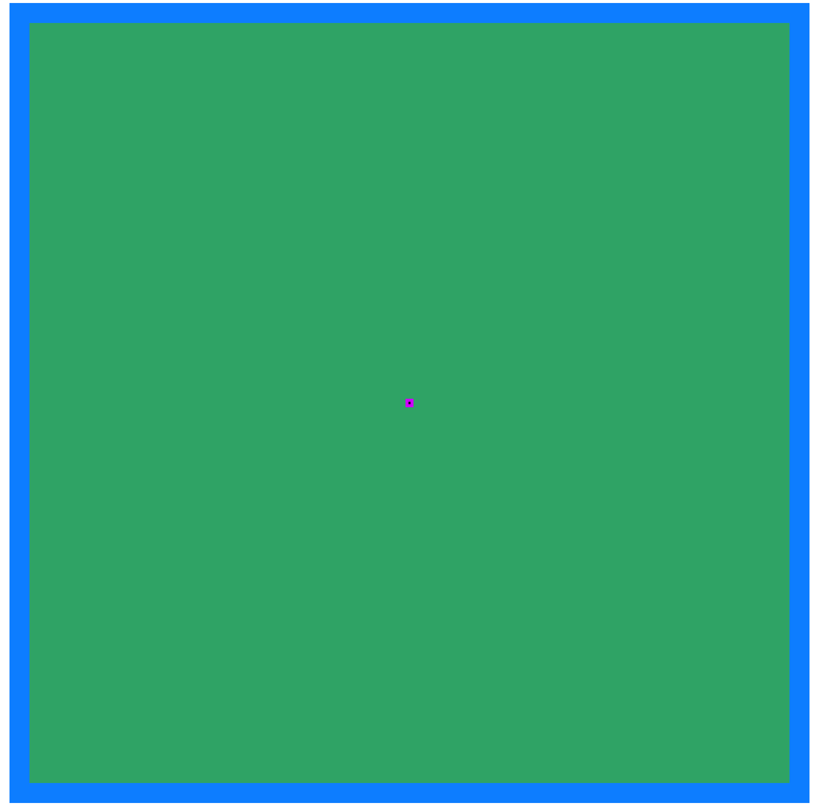
Need tools for targeting and monitoring of renovations.



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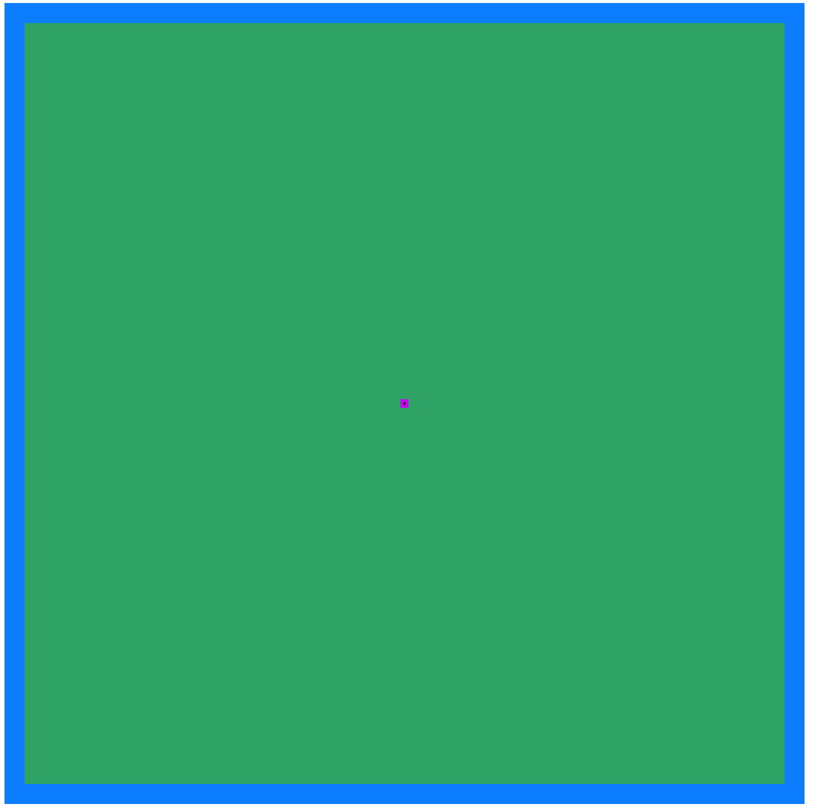
Finite Element Analysis (FEA)



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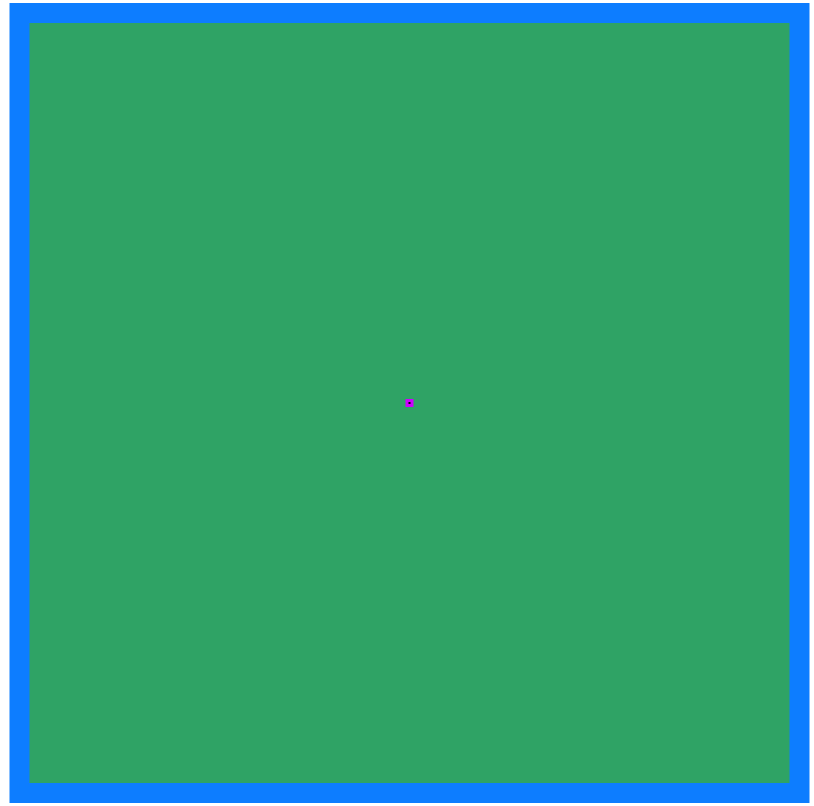
Finite Element Analysis (FEA)

- Tedious and error-prone modeling



Aim

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Simplify data collection for building renovation

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Research Question

Aim

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Research Question

Is it possible to use computer vision to simplify the generation of volumetric 3D models for Finite-Element Analysis (FEA)?

Existing 3D RGB+Thermal reconstruction

Take a sparse set of images of a building and estimate

1. Hassan et al. 2025, ThermoNeRF: A multimodal neural radiance field for joint RGB-thermal novel view synthesis of building facades, Advanced Engineering Informatics ↩
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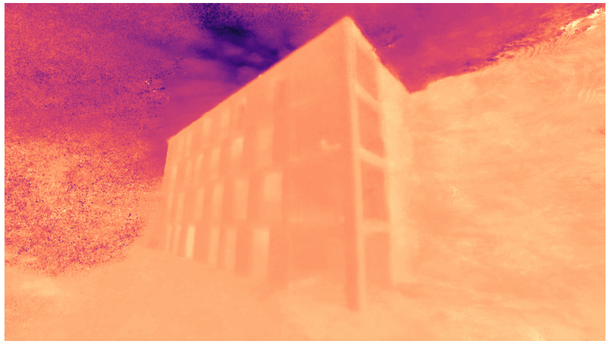

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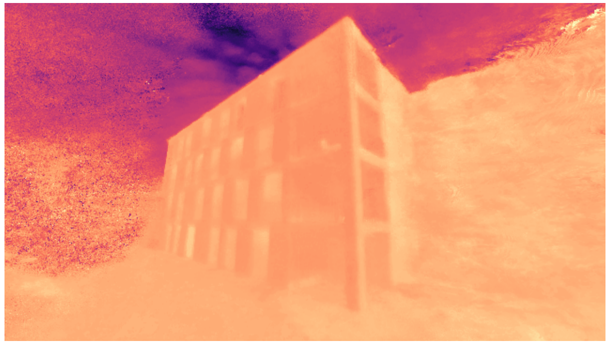

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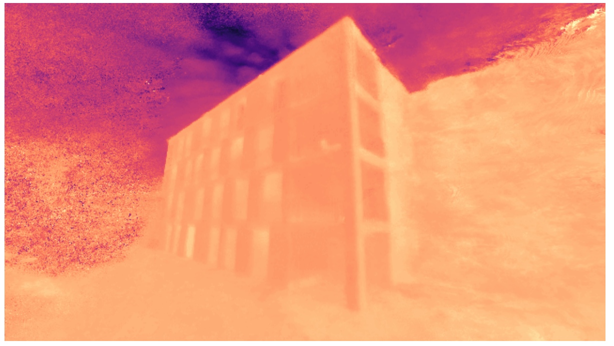
- NeRF for building facade novel view synthesis[1] - *No 3D model*



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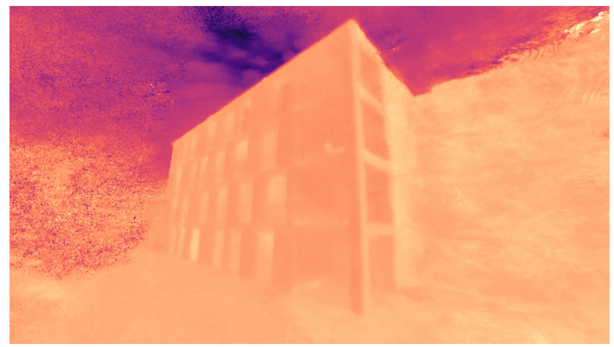

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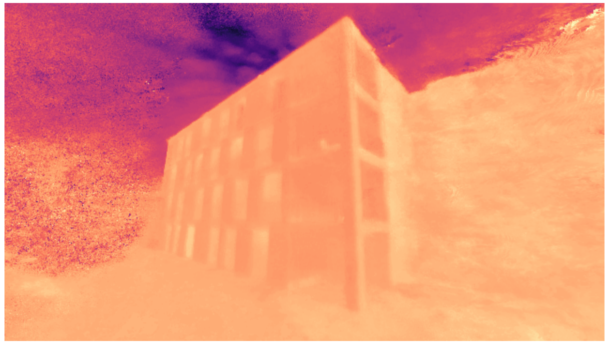

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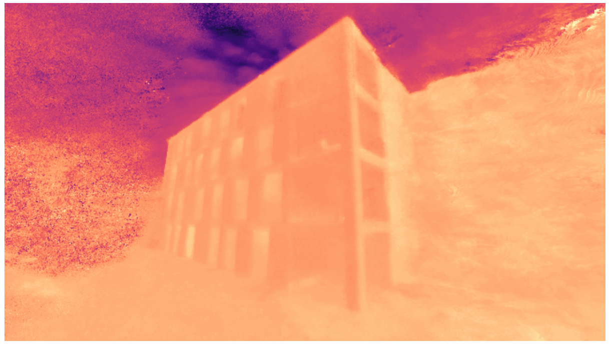

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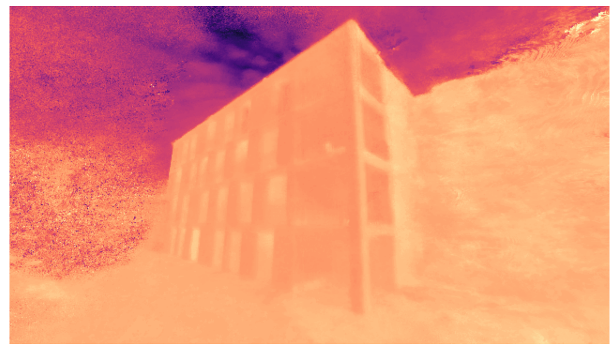
Not possible to simulate using FEA



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Thermoxels

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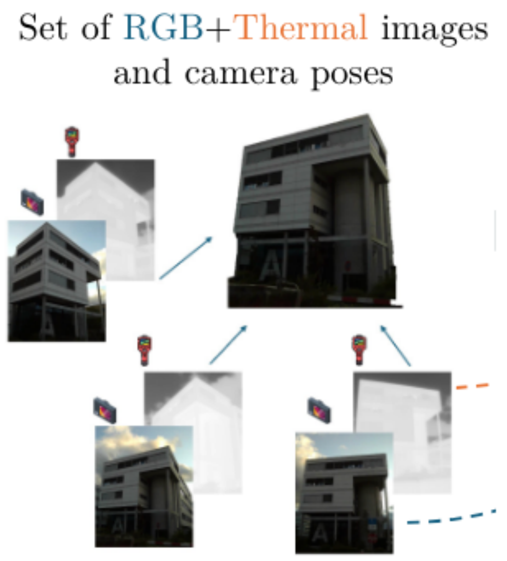
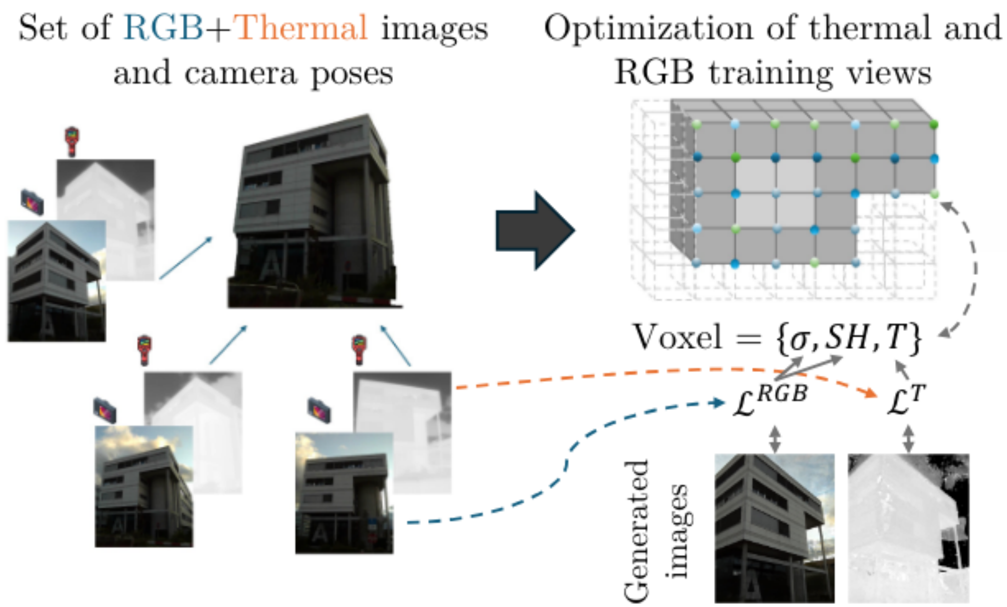
First method to convert sparse set of RGB+Thermal images to a Volumetric mesh compatible with FEA

Pose extraction



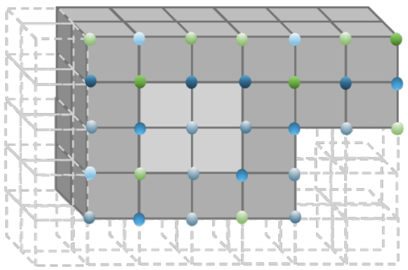

```
# Find poses on RGB with COLMAP
poses = COLMAP(images_rgb)
```

Voxel optimization



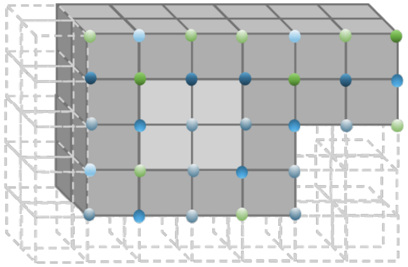

```
poses = COLMAP(images_rgb)
# optimize color and temperature on voxels
thermoxels = Voxels(scene_size)
while i <= max_iteration:
  rgb, temperature = thermoxels(images_rgb, images_thermal, poses)
  loss = Loss(rgb, temperature, rgb_gt, temperature_gt)
  thermoxels.optimize(loss)
```

Voxel optimization



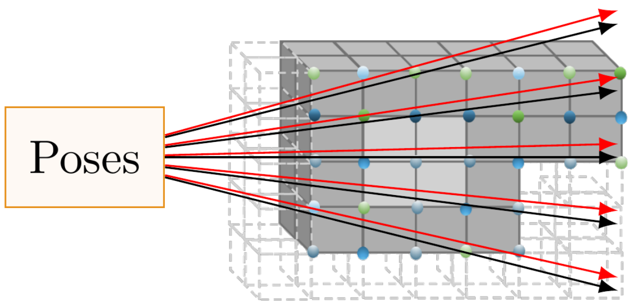
Voxel optimization

Poses



Schindler

Voxel optimization



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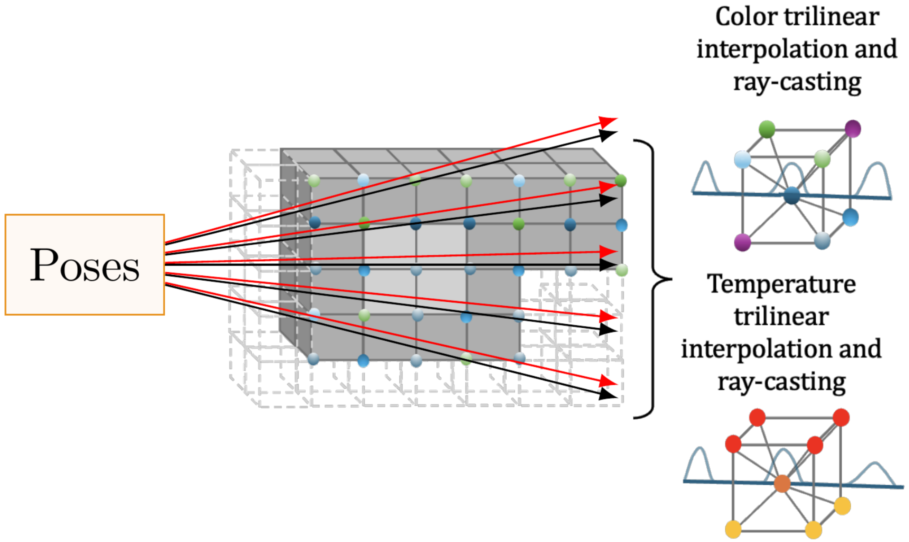

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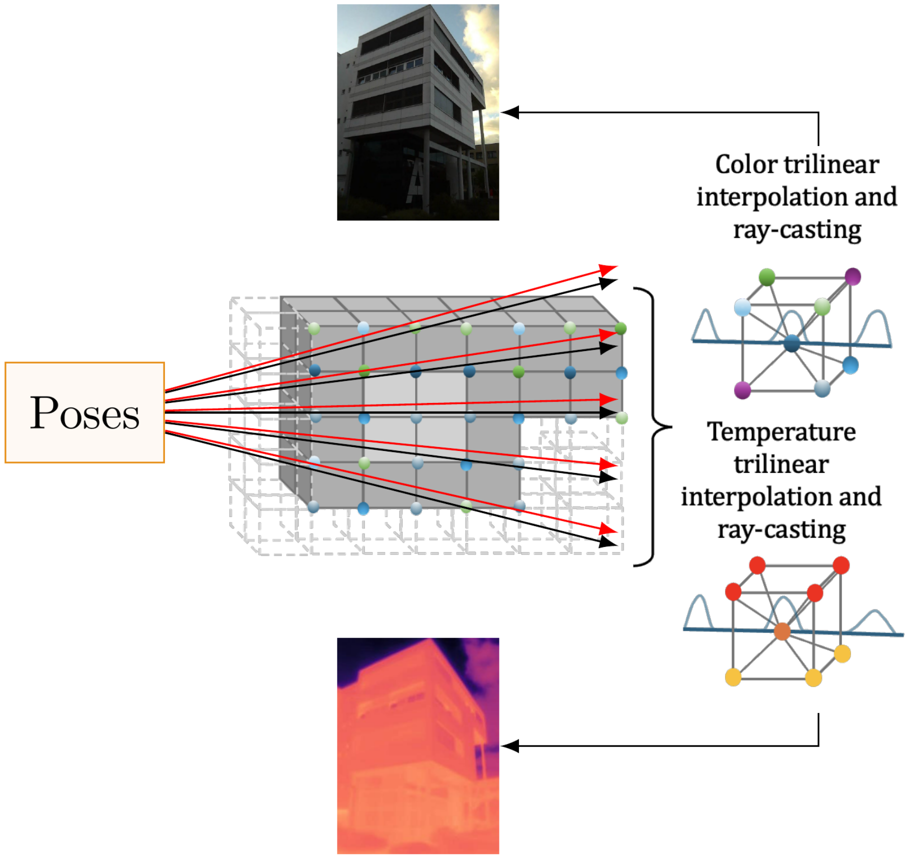

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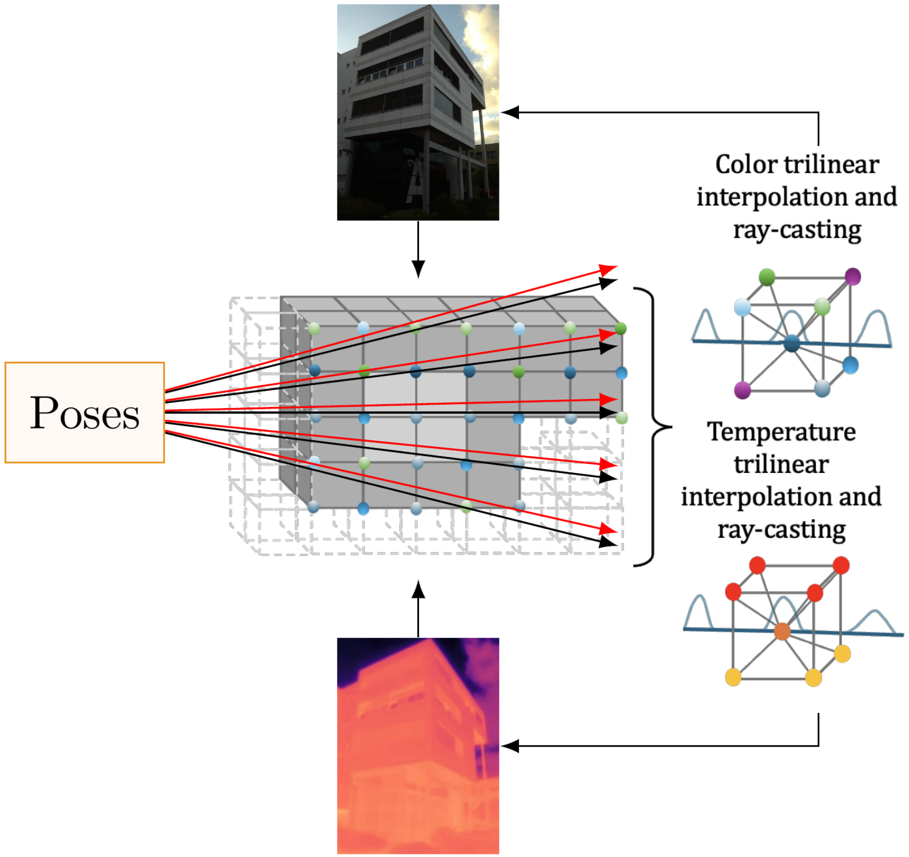

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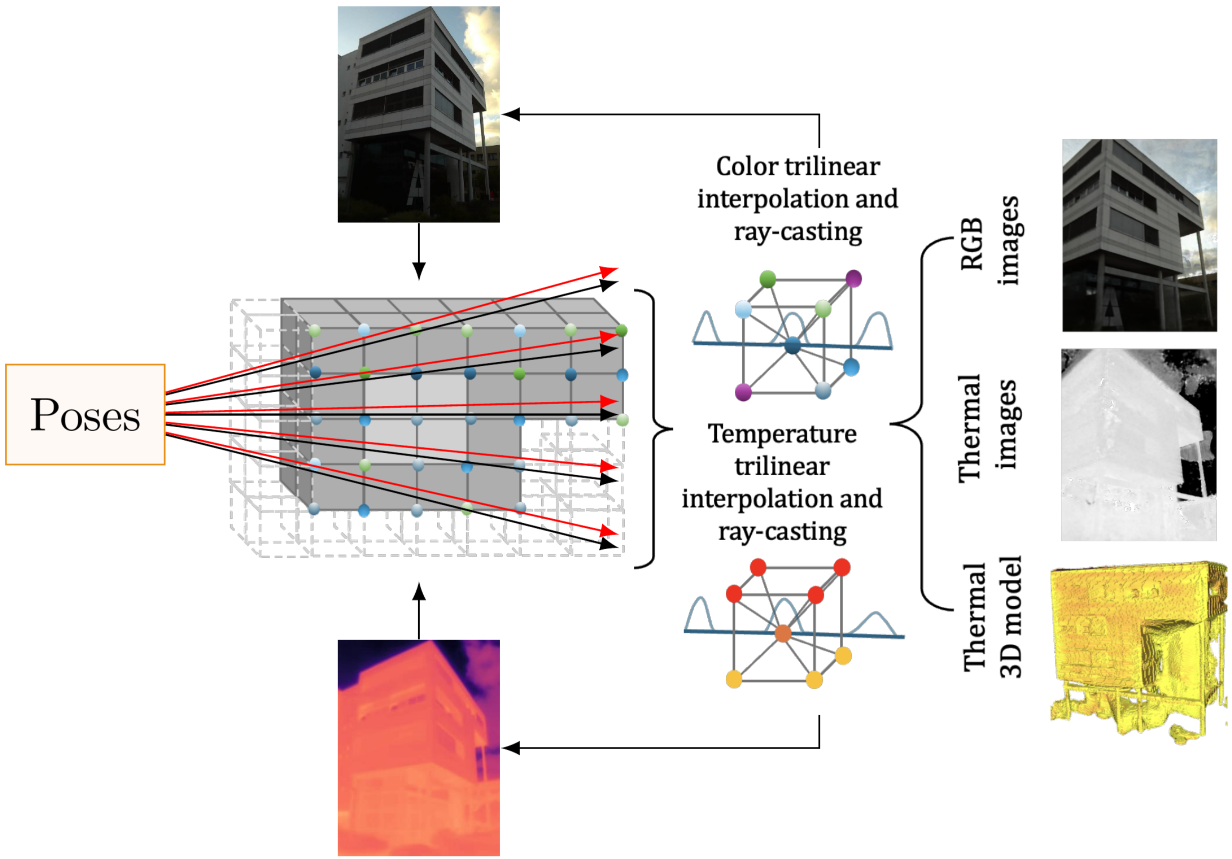

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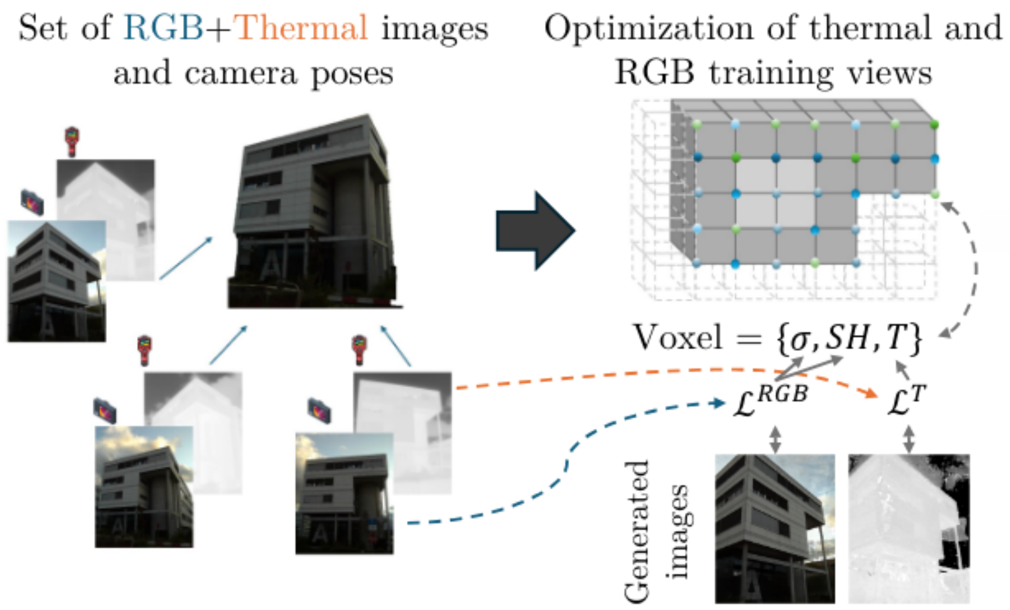


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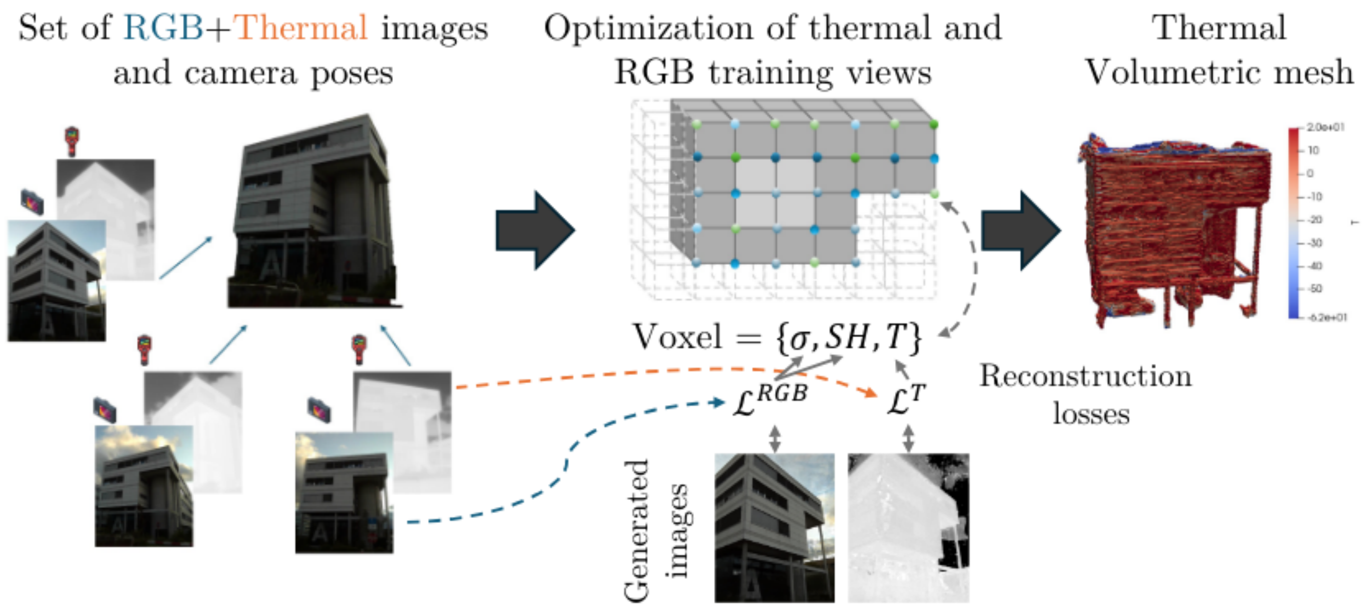
Volumetric Mesh Extraction

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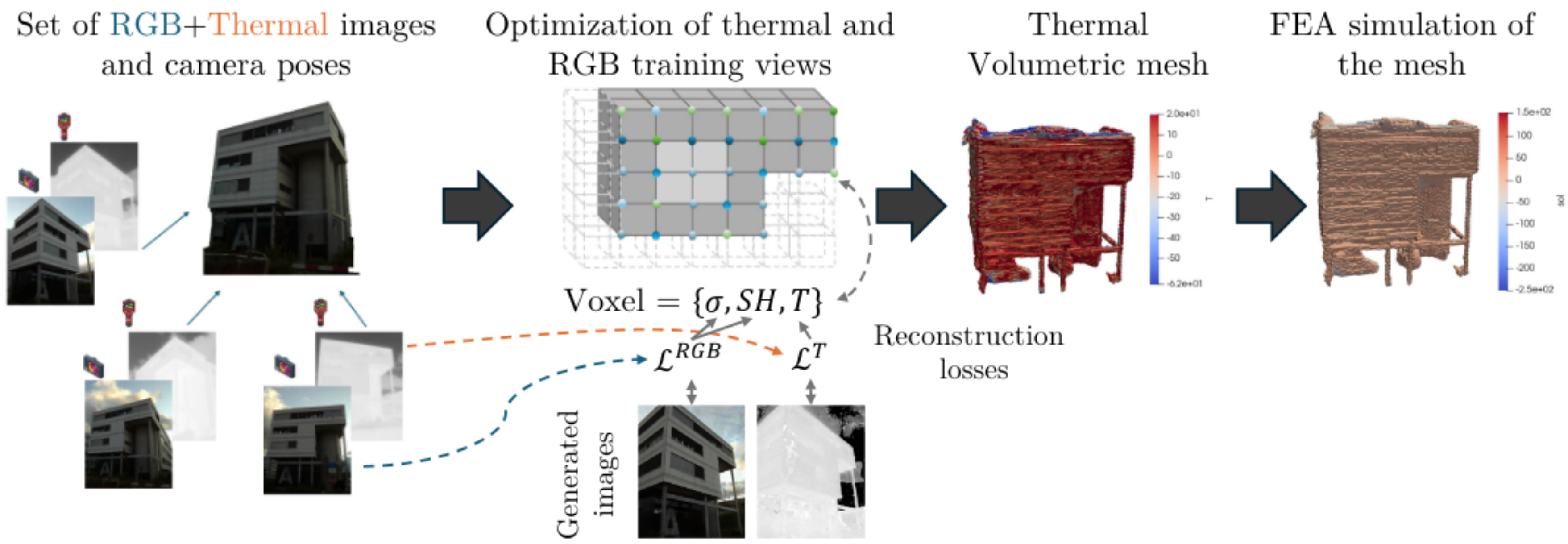
  loss = Loss(rgb, temperature, rgb_gt, temperature_gt)
  thermoxels.optimize(loss)
# Reconstruct thermal volumetric mesh
vol_mesh, surface_temperature = filtering(voxels, threshold)
```

Finite-Element Analysis

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  thermoxels.optimize(loss)
vol_mesh, surface_temperature = filtering(voxels, threshold)
# Run FEA simulation
simulation = FEA(vol_mesh, surface_temperature, env_conditions)
```

Results

Reconstruction Metrics

Method	Heated Water Cup	Heated Water Kettle	Melting Ice Cup	Building (spring)	Building (winter)	Double robot	Exhibition Building	Dorm 1	Dorm 2
ThermoNeRF	32.05	34.04	32.24	26.63	28.75	30.75	33.79	34.10	29.94
Plenoxels_t	31.93	34.40	42.05	35.24	34.62	33.29	27.50	39.24	35.50
Thermoxels	29.78	30.37	19.99	19.84	22.56	24.16	18.78	10.79	13.85

Figure 1: PSNR

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Thermoxels	29.78	30.37	19.99	19.84	22.56	24.16	18.78	10.79	13.85

Figure 1: PSNR

ThermoNeRF	0.92	0.94	0.98	0.92	0.88	0.95	0.97	0.96	0.95
Plenoxels_t	0.92	0.98	0.96	0.96	0.93	0.92	0.97	0.98	0.97
Thermoxels	0.83	0.92	0.88	0.90	0.82	0.75	0.86	0.60	0.72

Figure 2: SSIM

Reconstruction Metrics

Method	Heated Water Cup	Heated Water Kettle	Melting Ice Cup	Building (spring)	Building (winter)	Double robot	Exhibition Building	Dorm 1	Dorm 2
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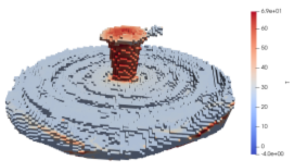
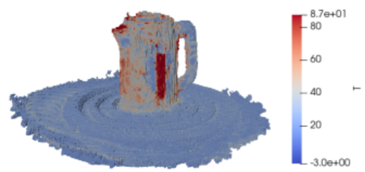
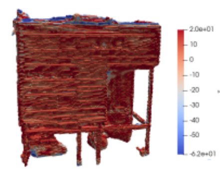
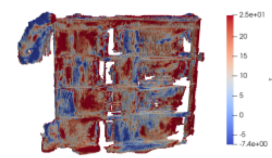
Plenoxels_t	0.92	0.98	0.96	0.96	0.93	0.92	0.97	0.98	0.97
Thermoxels	0.83	0.92	0.88	0.90	0.82	0.75	0.86	0.60	0.72

Figure 2: SSIM

ThermoNeRF	2.10	2.76	1.57	1.88	0.66	0.91	0.31	0.38	0.75
Plenoxels_t	0.87	1.41	0.11	1.36	0.40	0.49	1.00	0.32	0.39
Thermoxels	0.99	1.15	1.74	5.29	1.27	0.74	1.29	8.87	4.21

Figure 3: MAE

Simulation ready models

Scene	Cup	Kettle	Building A spring	Dorm 1	Dorm 2
Thermoxels (Ours)					

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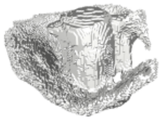
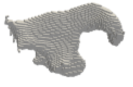
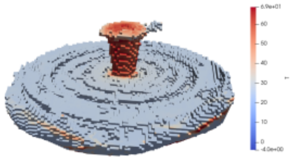
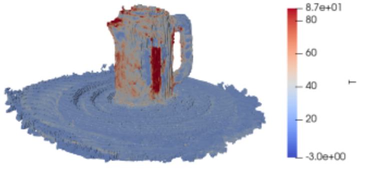
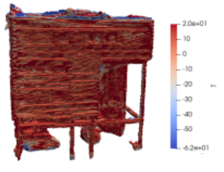
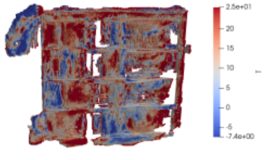
Plenoxels$_t$					
Thermoxels (Ours)					

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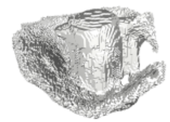
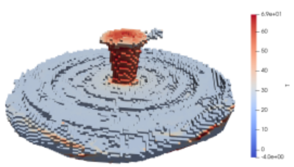
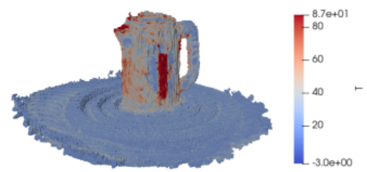
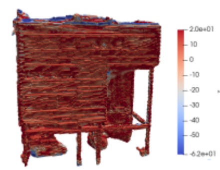
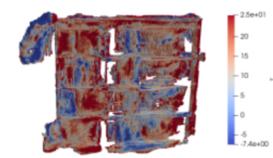
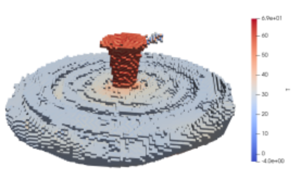
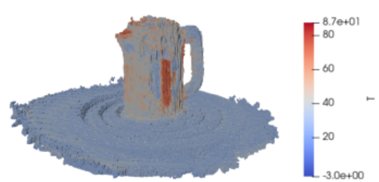
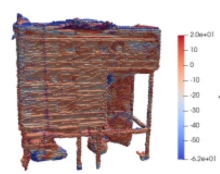
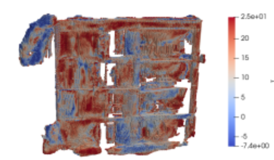
Scene	Cup	Kettle	Building A spring	Dorm 1	Dorm 2
Plenoxels$_t$					
Thermoxels (Ours)					
Thermoxels After FEA					

Thermoxels temperature as initial condition

Conclusion and Future Work

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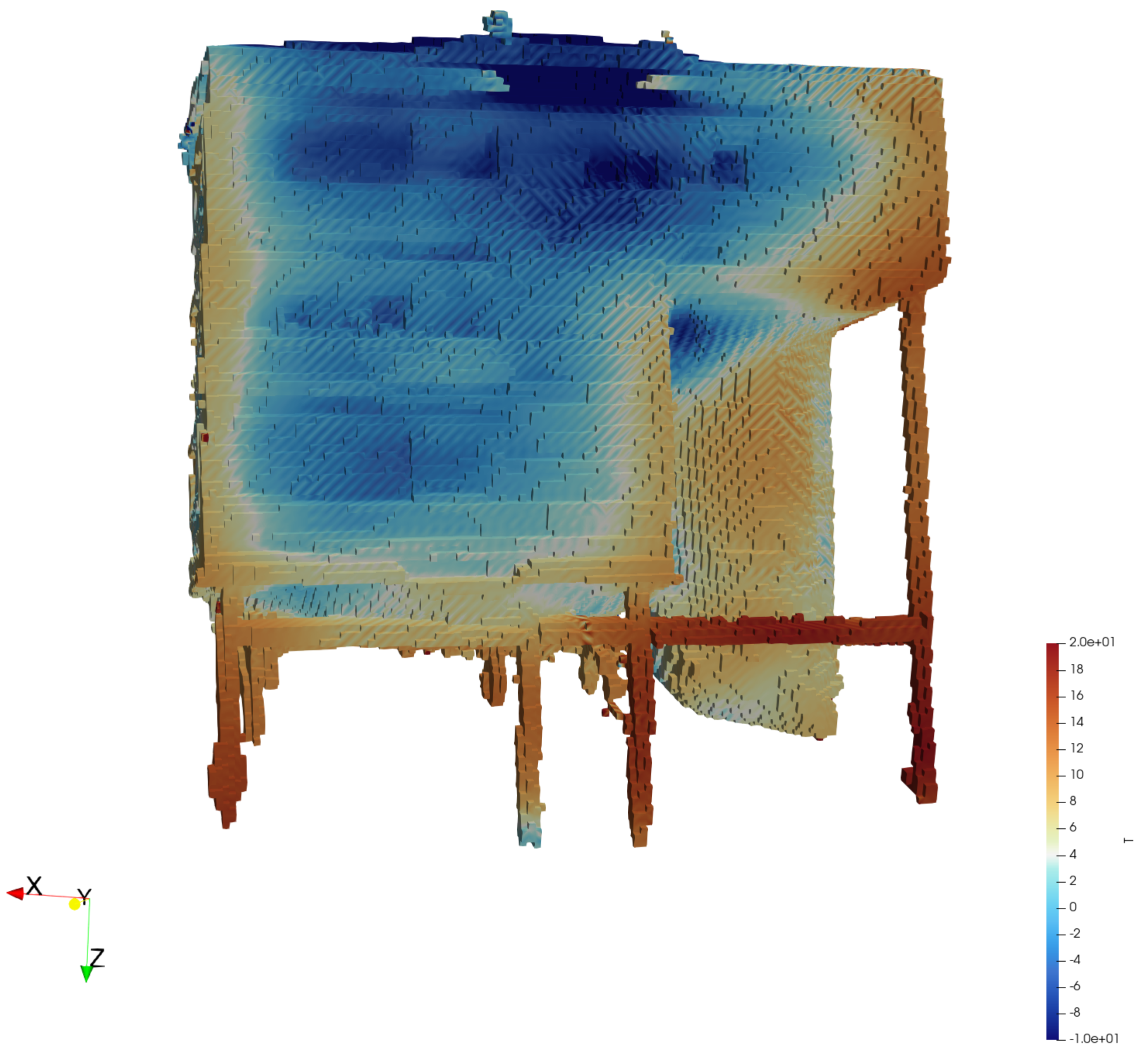
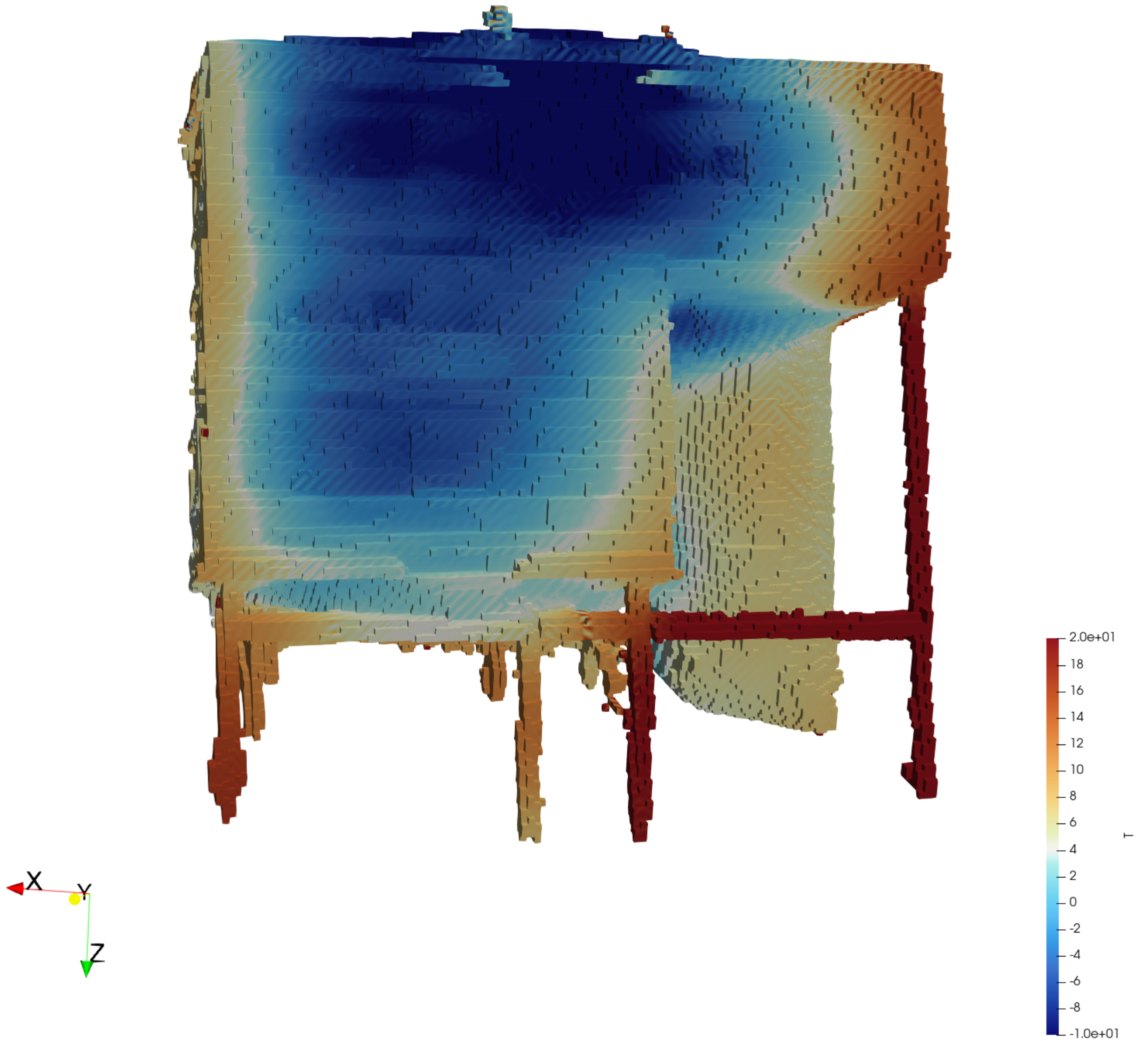
Conclusion



Conclusion



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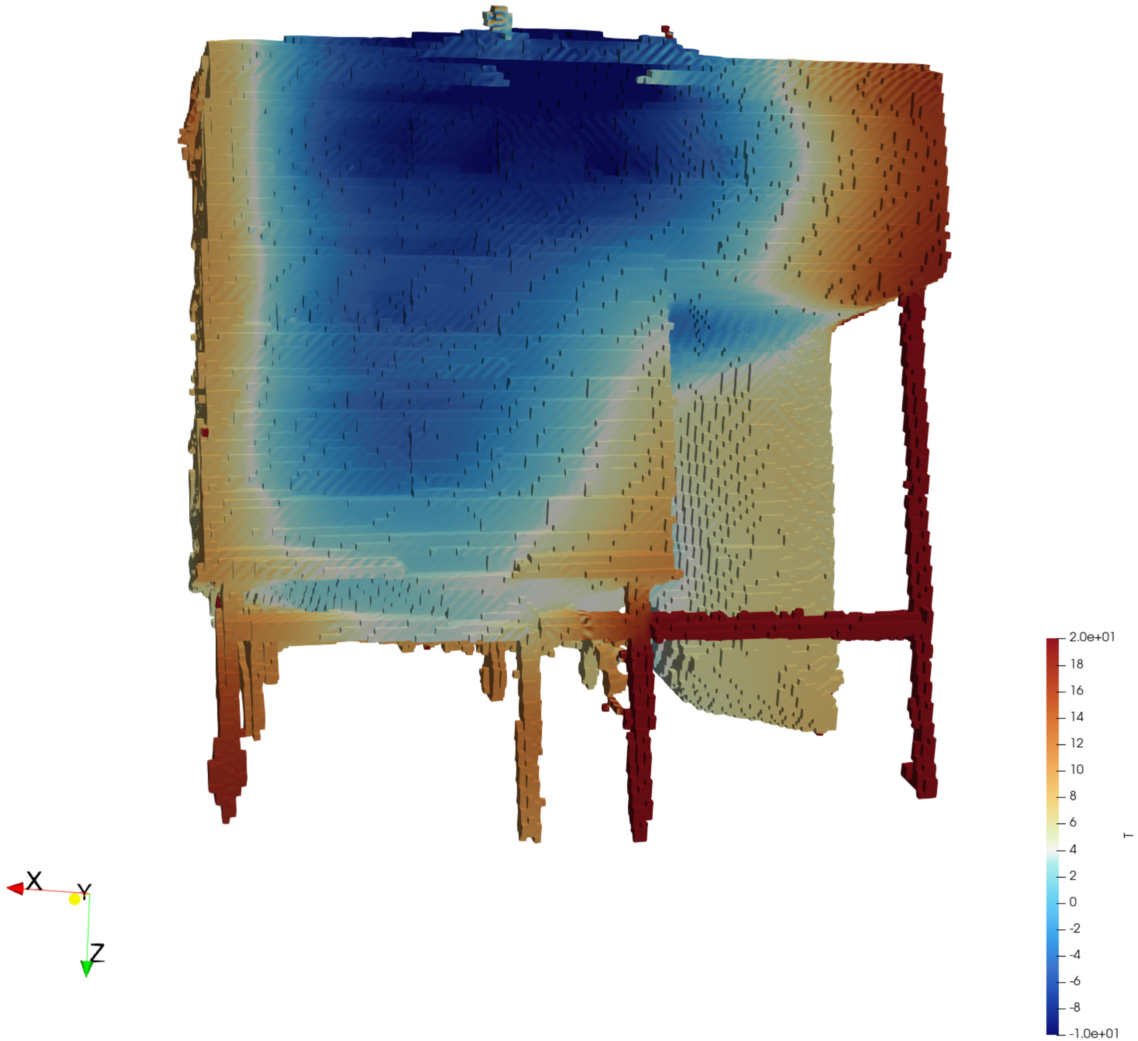

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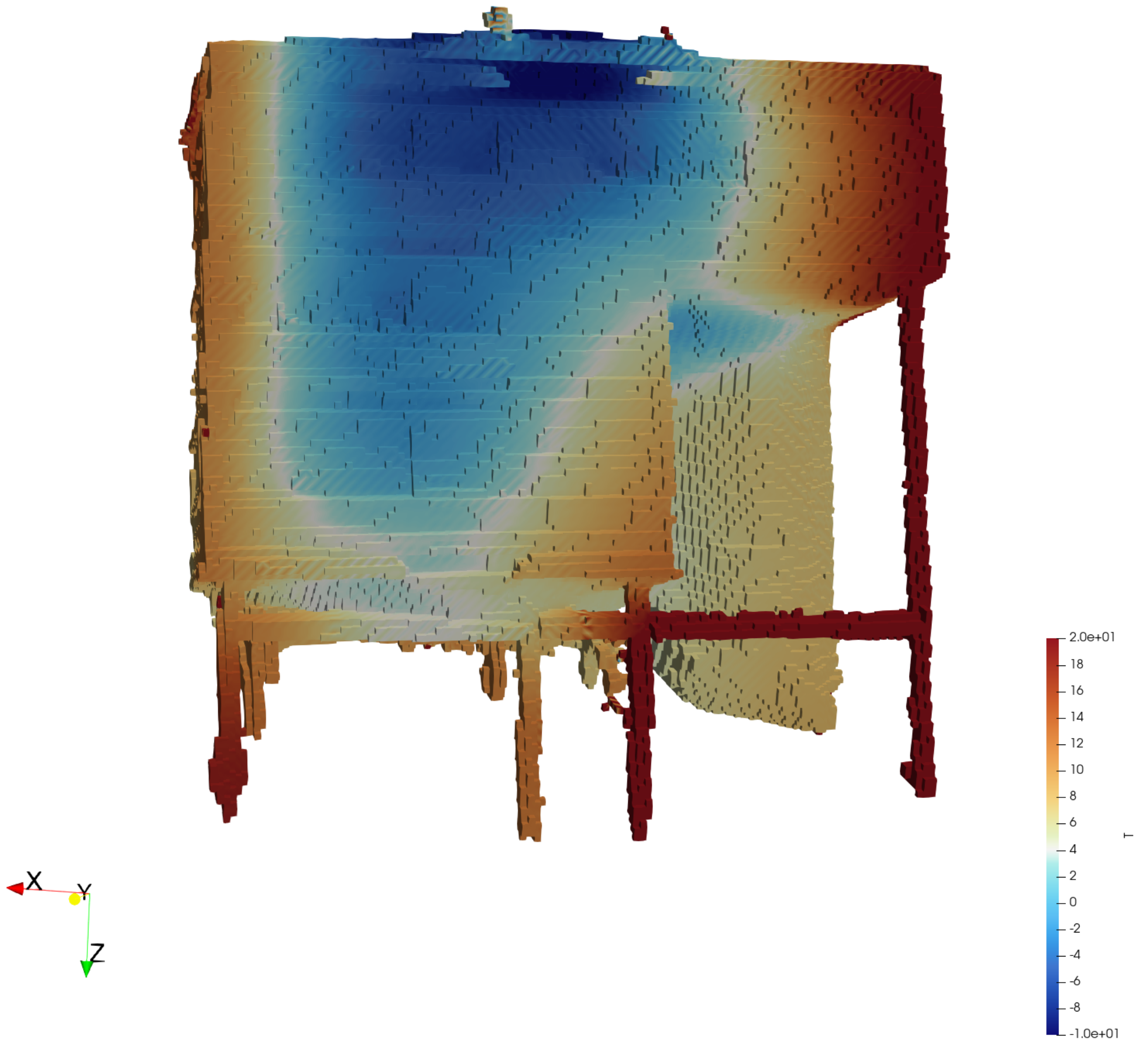

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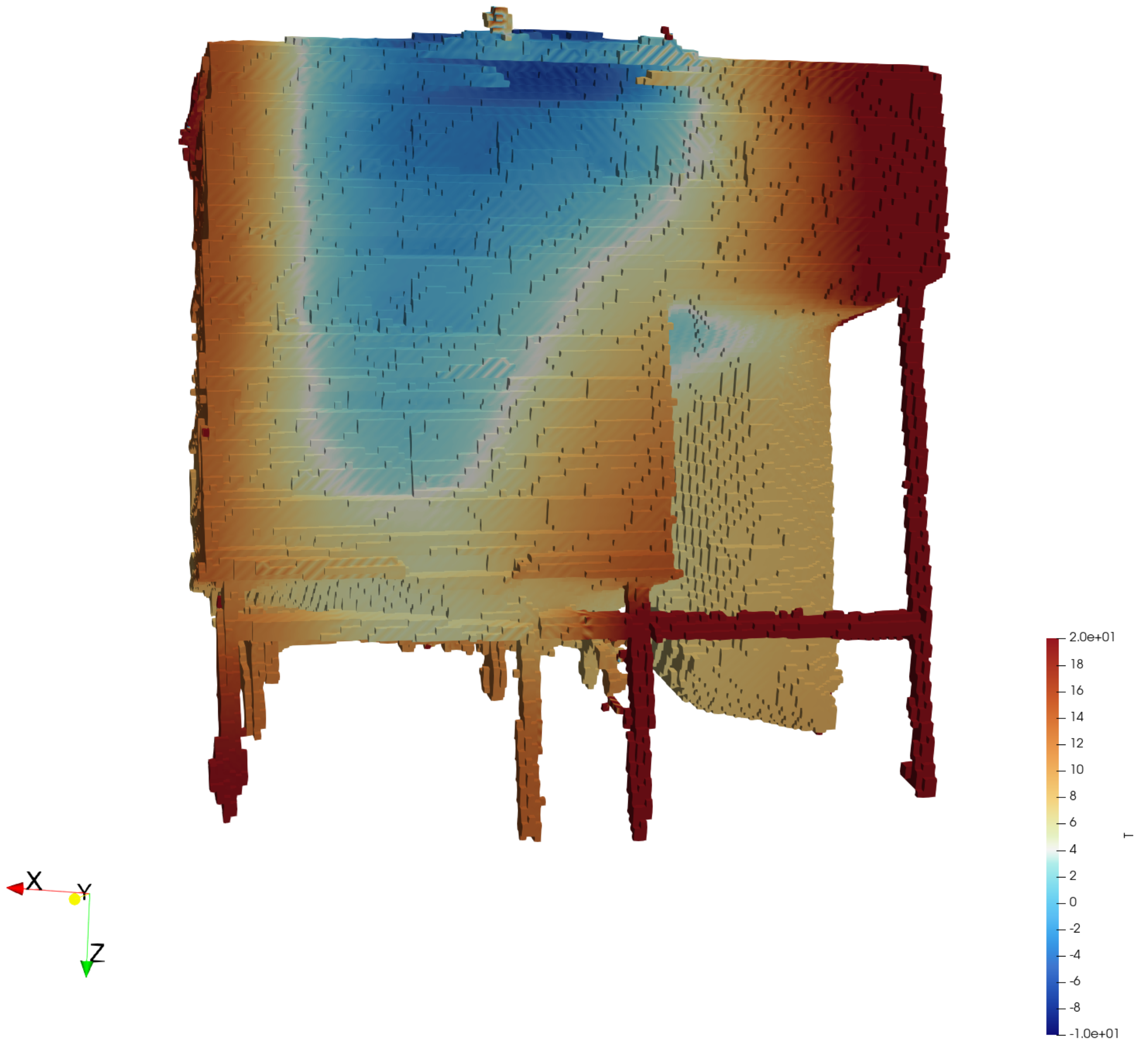

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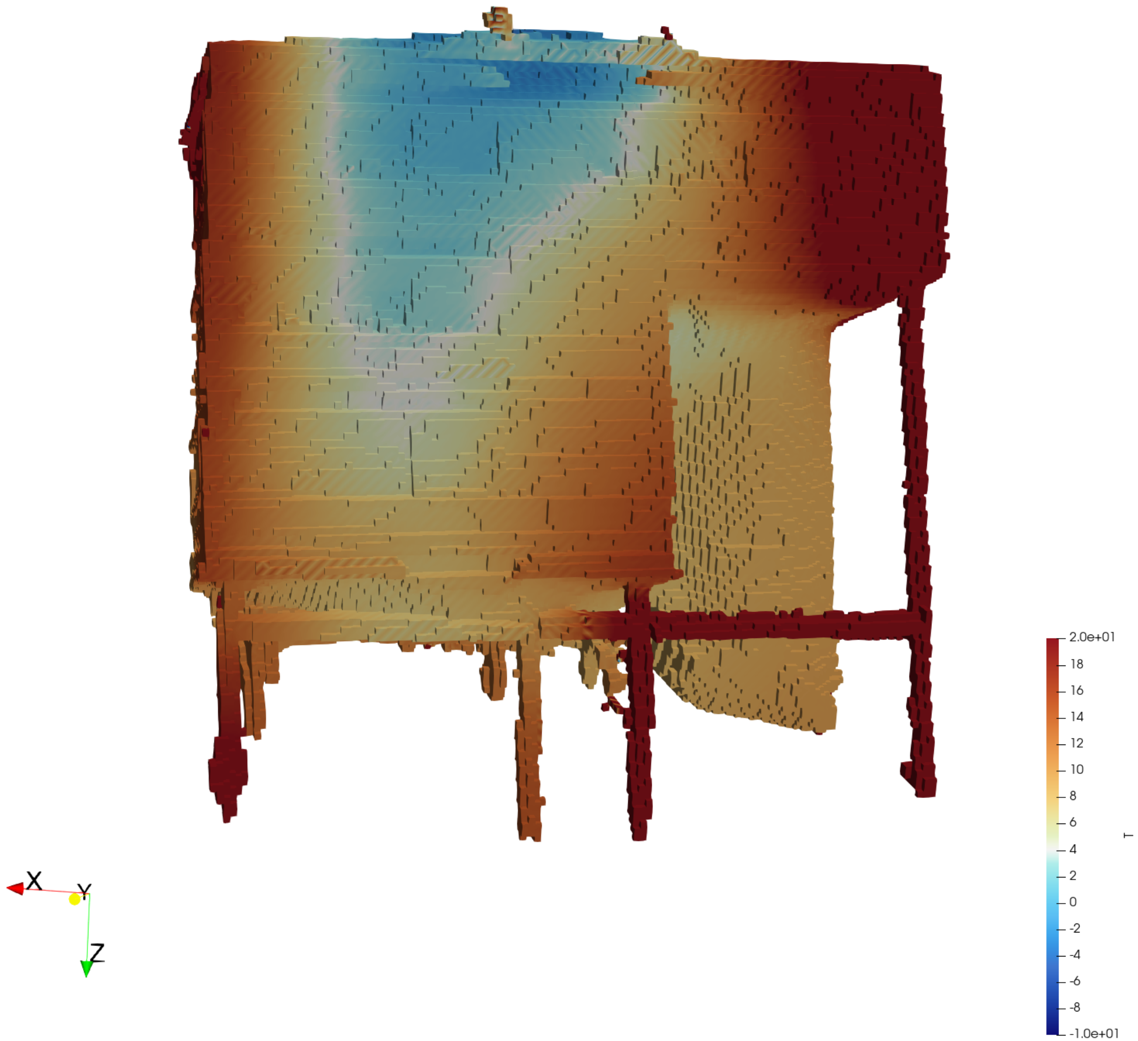
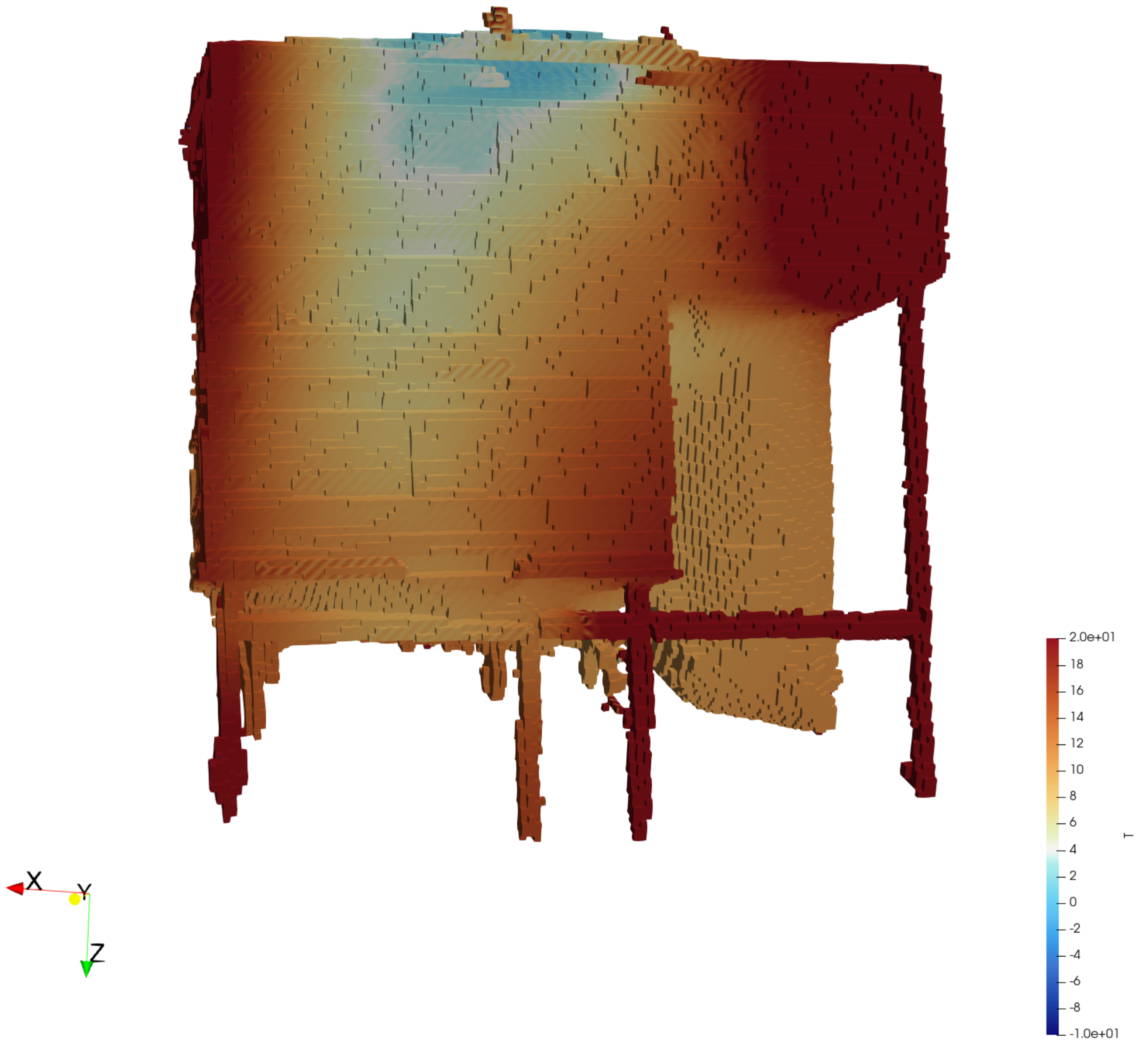


Conclusion



References

Chen, Q., Shu, S., & Bai, X. (2025). Thermal3D-GS: Physics-induced 3D gaussians for thermal infrared novel-view synthesis. In A. Leonardis, E. Ricci, S. Roth, O. Russakovsky, T. Sattler, & G. Varol (Eds.), *Computer vision – ECCV 2024* (pp. 253–269). Springer Nature Switzerland.

Fridovich-Keil, S., Yu, A., Tancik, M., Chen, Q., Recht, B., & Kanazawa, A. (2022). Plenoxels: Radiance fields without neural networks. *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, 5501–5510.

Hassan, M., Forest, F., Fink, O., & Mielle, M. (2025). ThermoNeRF: A multimodal neural radiance field for joint RGB-thermal novel view synthesis of building facades. *Advanced Engineering Informatics*, *65*, 103345. https://doi.org/10.1016/j.aei.2025.103345