

Building Copenhagen in a Day*

Supplementary Material for: Out-of-Core Surface Reconstruction via Global TGV Minimization.

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In this supplementary, we want to show a public dataset with aerial photos of Copenhagen that we processed with our out-of-core surface reconstruction method. Additionally, we provide closeups of the resulting model with per-vertex colors and breakdowns of other three datasets discussed in the paper – see Tables 2, 3, 4.

We downloaded 500 blocks (tiles) of photos covering 425 km^2 of the Copenhagen city from publicly available aerial photos of Denmark¹ [1]. The downloaded blocks are shown in Fig. 1. For convenience, their names are also listed in the attached supplementary text file blocks.txt. These 500 blocks (each covers 1 km^2) contain 27472 aerial photos (566 GB) with resolutions of 13470x8670 and 10300x7700. In addition to nadir photos, there is also oblique imagery – one of such photos is shown in Fig. 3.

For speedup, we downscaled these photos with a factor of 4 before running the SGM-based [2] depthmap reconstruction. This dataset was evaluated twice - on a small cluster of 7 affordable computers (on the average each computer was a PC with an 8-core CPU and a GeForce GTX 1080 GPU) and on a single computer with an 8-core CPU and a GeForce GTX 1080 GPU. The surface reconstruction took 29 hours on a small cluster of 7 computers, and the processing took 5.5 days on a single computer. The breakdown of the processing on a cluster is shown in Table 1. The whole model with per-vertex color is shown in Fig. 2.

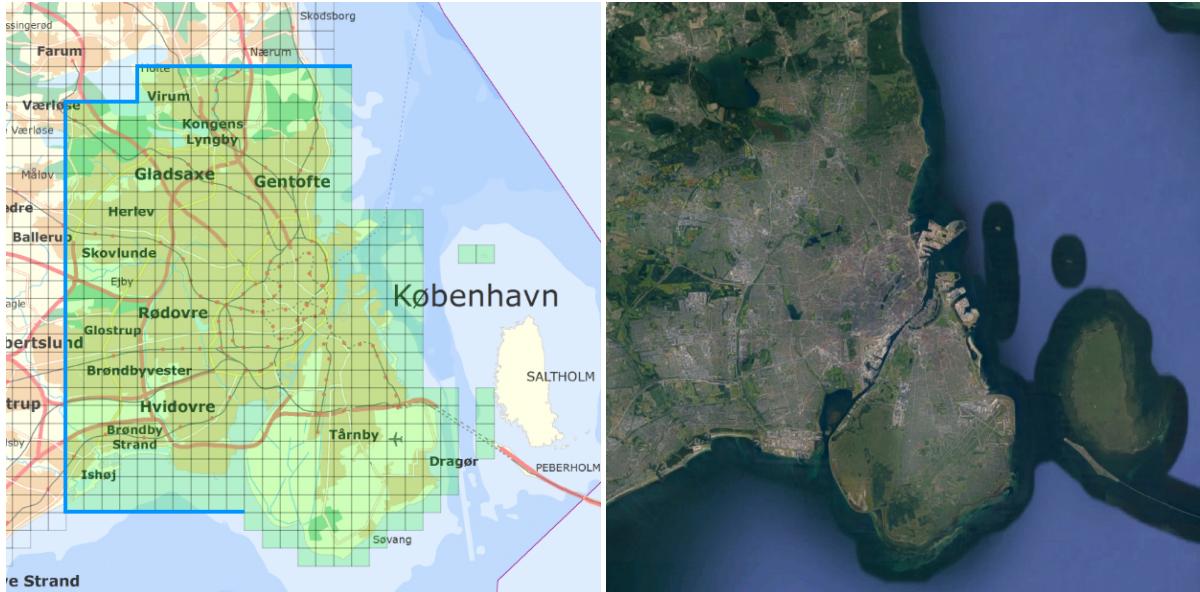


Figure 1. Copenhagen dataset [1]: 500 processed green blocks are shown (outlined with a blue border). To the right, a corresponding google map is shown [3].

*In 29 hours

¹<https://download.kortforsyningen.dk/content/skraafoto>

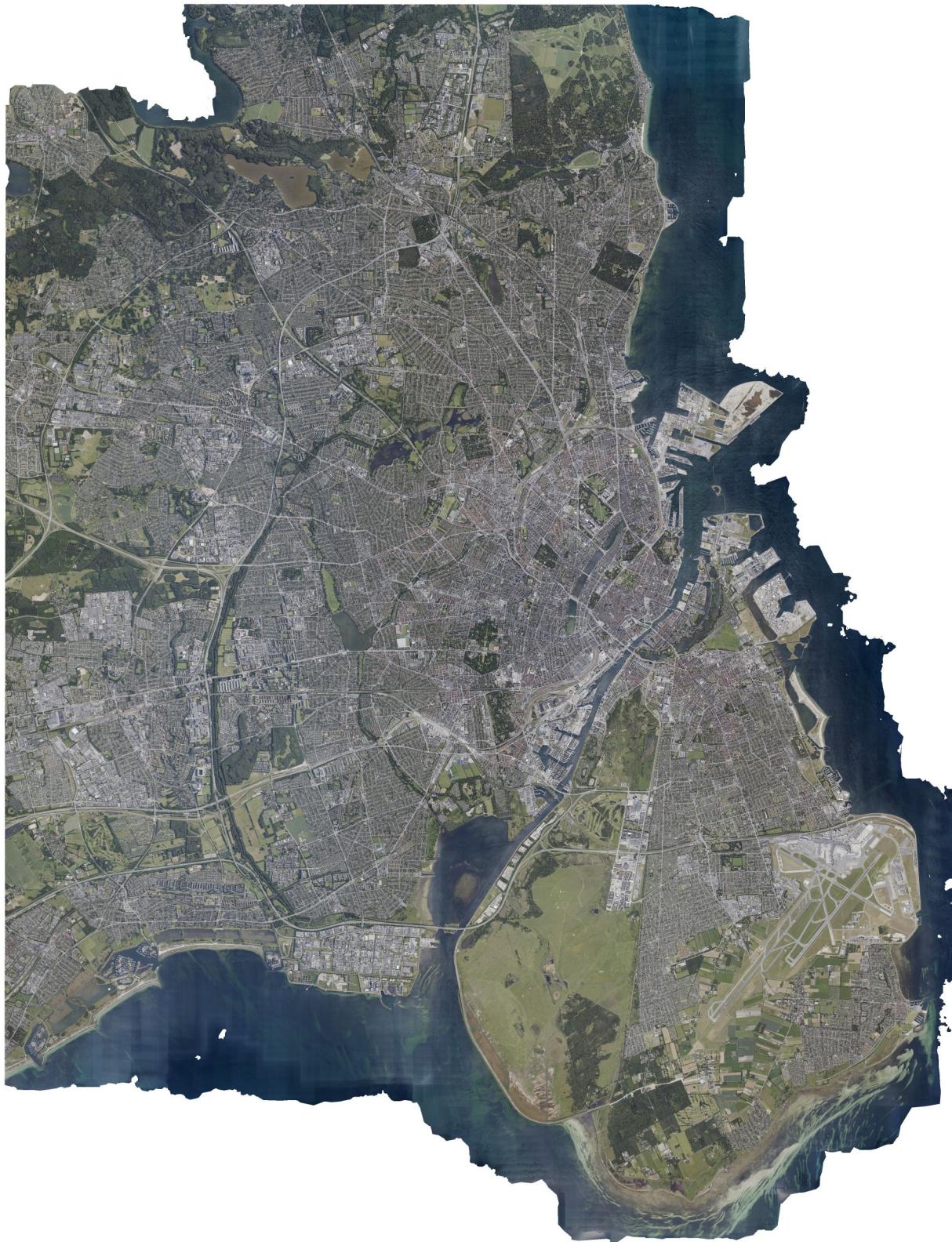


Figure 2. Our method can handle an arbitrary large scene – even 425 km^2 of the Copenhagen city. This polygonal model, consisting of 267 million triangles with per-vertex colors, was reconstructed from depth maps of 27472 aerial photos in 29 hours.

Table 1. A breakdown of the Copenhagen city dataset processing: 27472 photos, 28 billion cubes from input depth maps, 29 hours of processing on a 7-computers cluster with the peak RAM usage – 13.35 GB.

Processing stage	Time	Time in %
Linear octree parts + merge	173 + 149 min	10% + 8%
Balance octree parts + merge	141 + 199 min	8% + 11%
Index treetop	80 min	5%
Histograms (GPU)	393 min	22%
Primal-dual method (GPU)	159 min	9%
Marching cubes	445 min	25%

Table 2. A breakdown of the Citywall dataset processing: 564 photos, 1205 million cubes from input depth maps, 63 minutes of processing on a computer with a 8-core CPU and a GeForce GTX 1080 GPU with the peak RAM usage – 13.17 GB.

Processing stage	Time	Time in %
Linear octree + merge	7 + 4 min	10% + 6%
Balance octree + merge	2 + 2 min	3% + 3%
Index treetop	2 min	3%
Histograms (GPU)	17 min	26%
Primal-dual method (GPU)	18 min	28%
Marching cubes	12 min	18%

Table 3. A breakdown of the Palacio Tschudi dataset processing: 13703 photos, 16 billion cubes from input depth maps, 20 hours of processing on a computer with an 8-core CPU and a GeForce GTX 1080 GPU with the peak RAM usage – 16.75 GB.

Processing stage	Time	Time in %
Linear octree + merge	66 + 68 min	5% + 5%
Balance octree + merge	28 + 56 min	2% + 5%
Index treetop	32 min	2%
Histograms (GPU)	370 min	30%
Primal-dual method (GPU)	360 min	30%
Marching cubes	240 min	20%

Table 4. A breakdown of the Tomb of Tu Duc LIDAR dataset processing: 42 LIDAR scans, 661 million cubes from input LIDAR scans, 160 minutes of processing on a computer with an 8-core CPU with a GeForce GTX 1080 GPU with peak RAM usage – 10.05 GB.

Processing stage	Time	Time in %
Linear octree + merge	4 + 3 min	3% + 2%
Balance octree + merge	5 + 21 min	3% + 13%
Index treetop	6 min	4%
Histograms (GPU)	14 min	9%
Primal-dual method (GPU)	54 min	34%
Marching cubes	53 min	33%

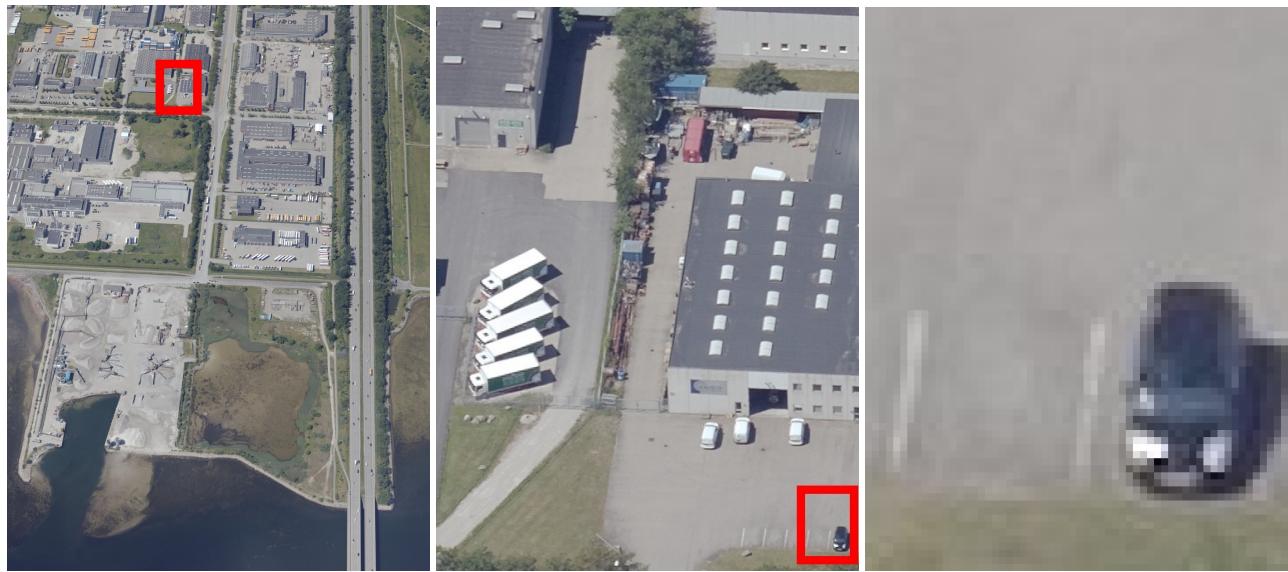


Figure 3. Example of oblique photo with resolution 7700x10300. skraa_1km_6168_720.JPG_UTM32-ETRS89.zip / 2019_84_40_5_0034_00002391.jpg



Figure 4. Frederiksberg Forsyning A/S closeup. Note that both pipes were reconstructed well.

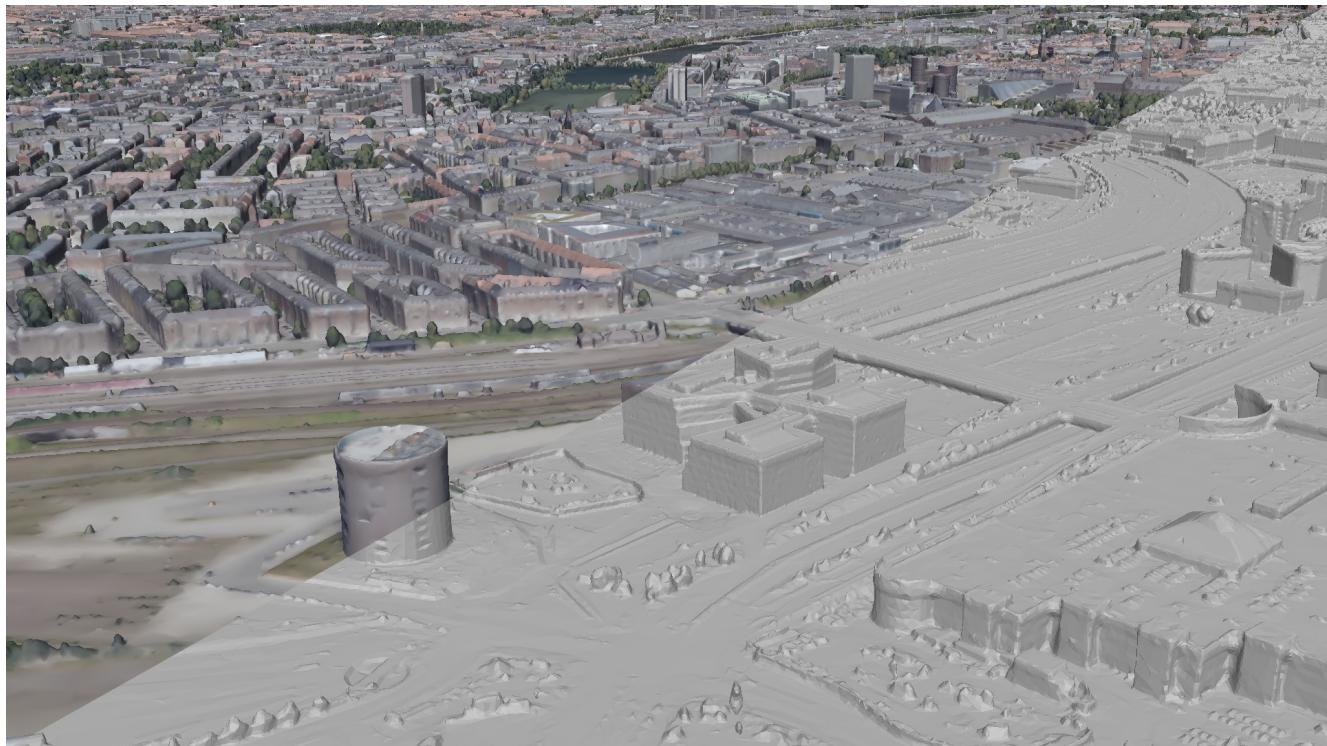


Figure 5. Banedanmark closeup.

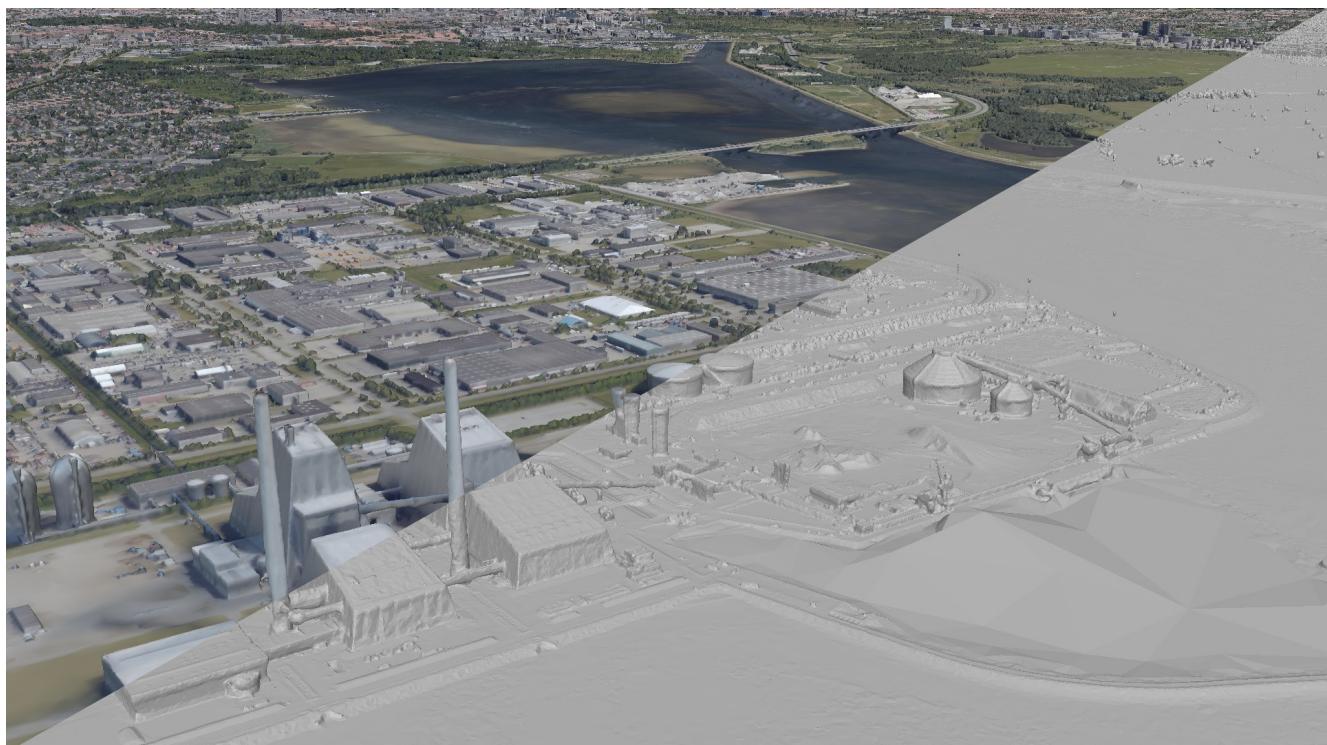


Figure 6. Avedøre Power Station closeup. Note accurate geometry of thin structures above the ground.

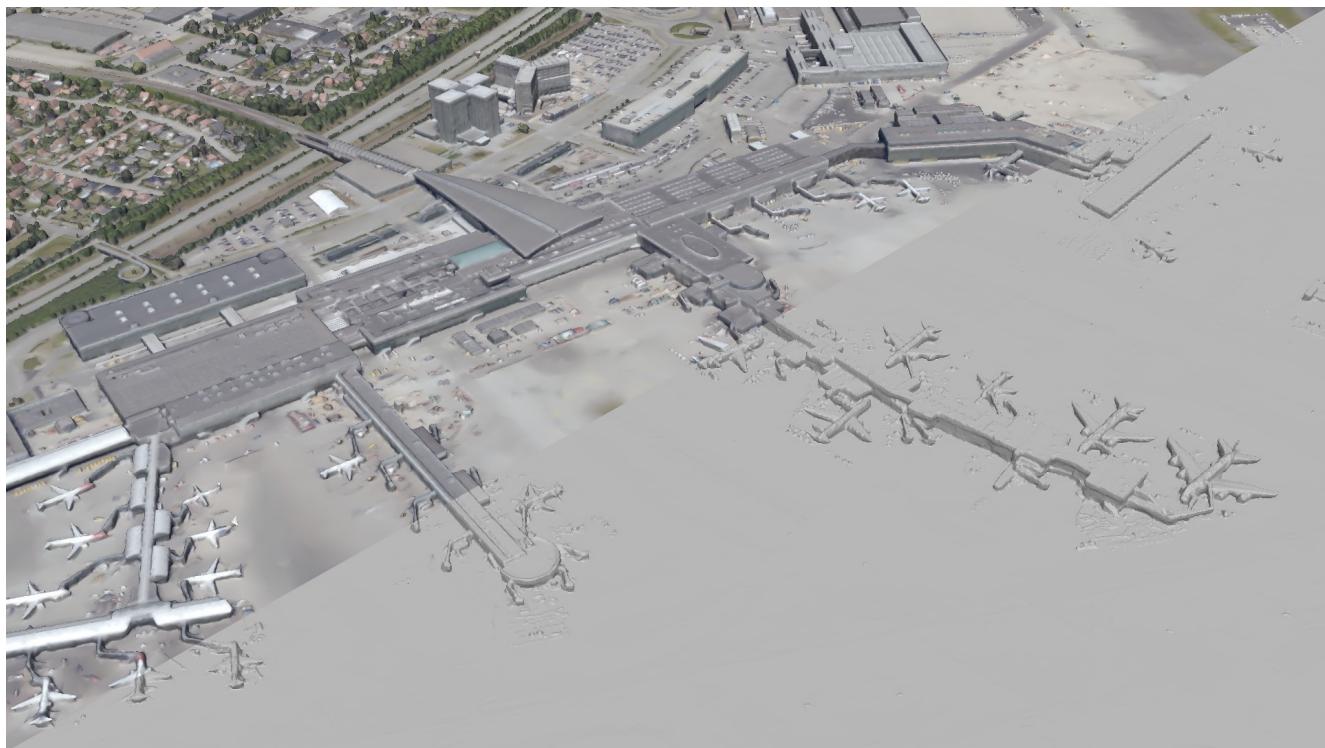


Figure 7. Airport closeup.

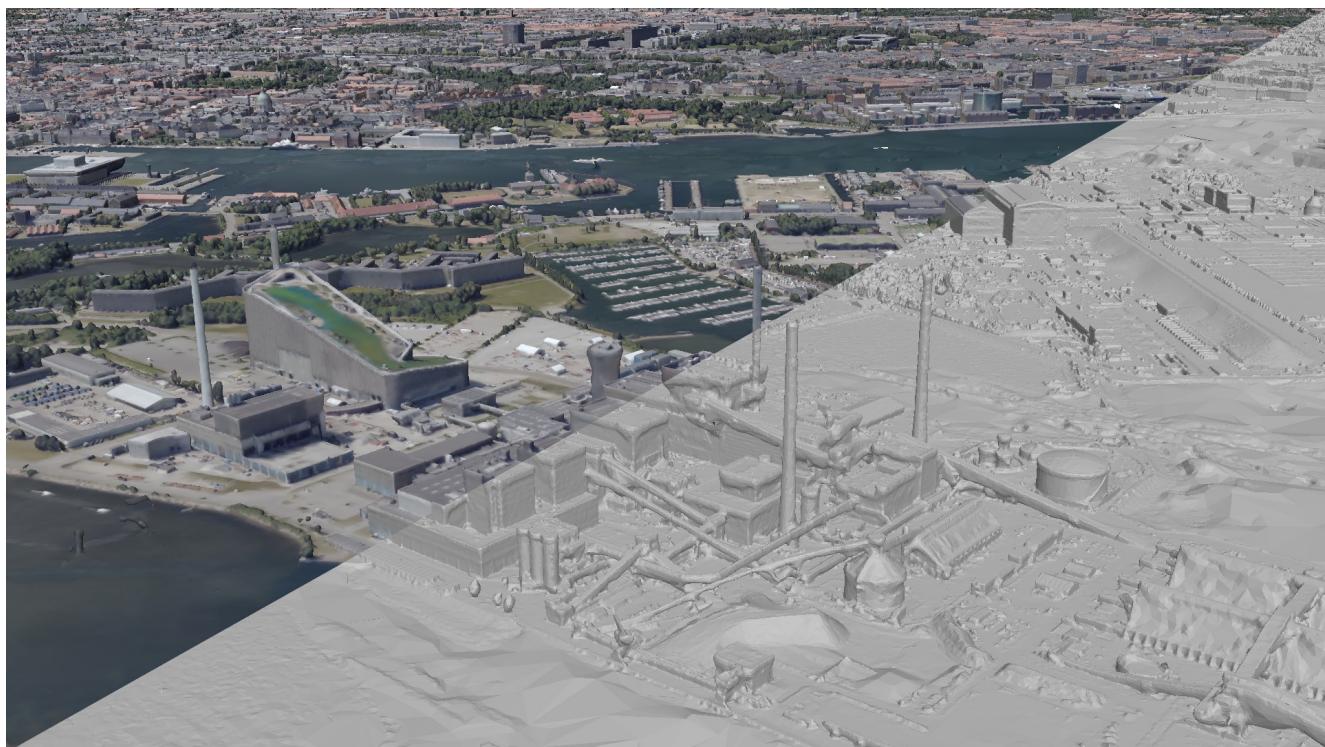


Figure 8. Hofor Amagerverket closeup.

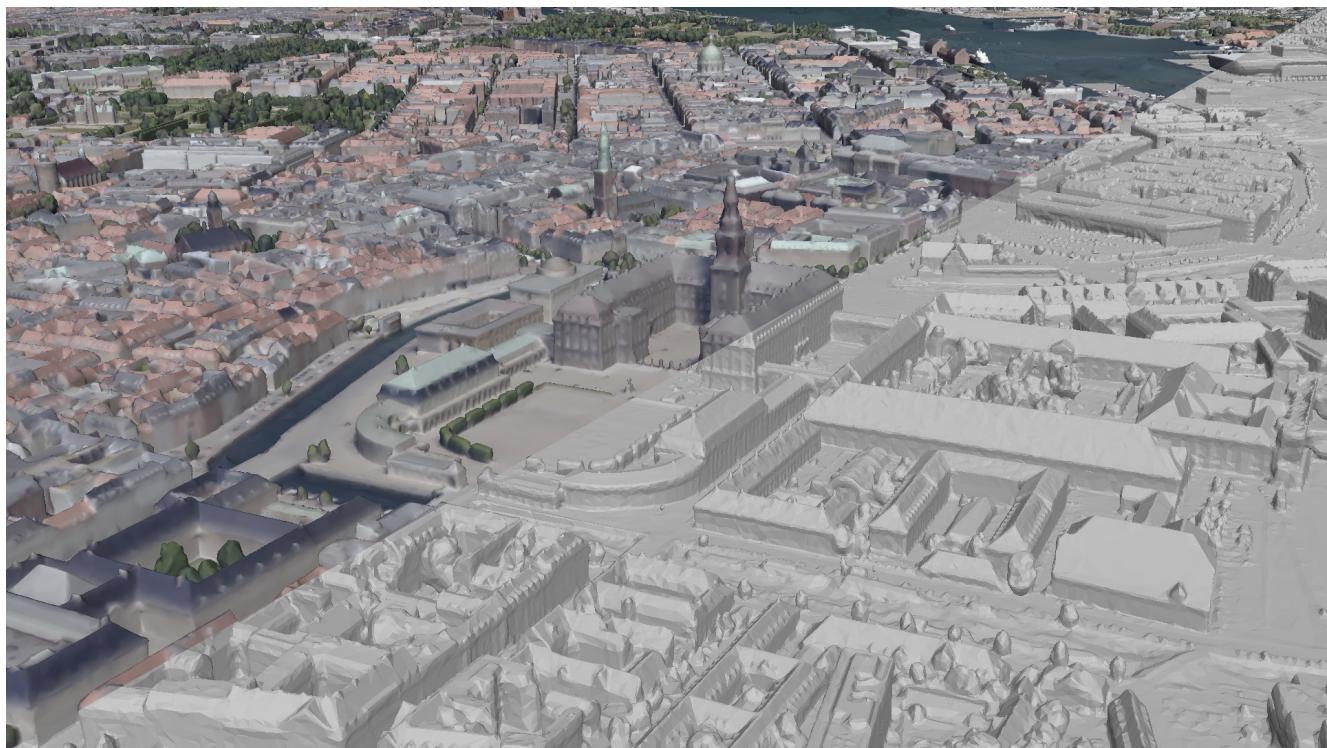


Figure 9. Christiansborg Palace closeup.



Figure 10. Kastellet closeup.



Figure 11. Frederik's Church closeup.

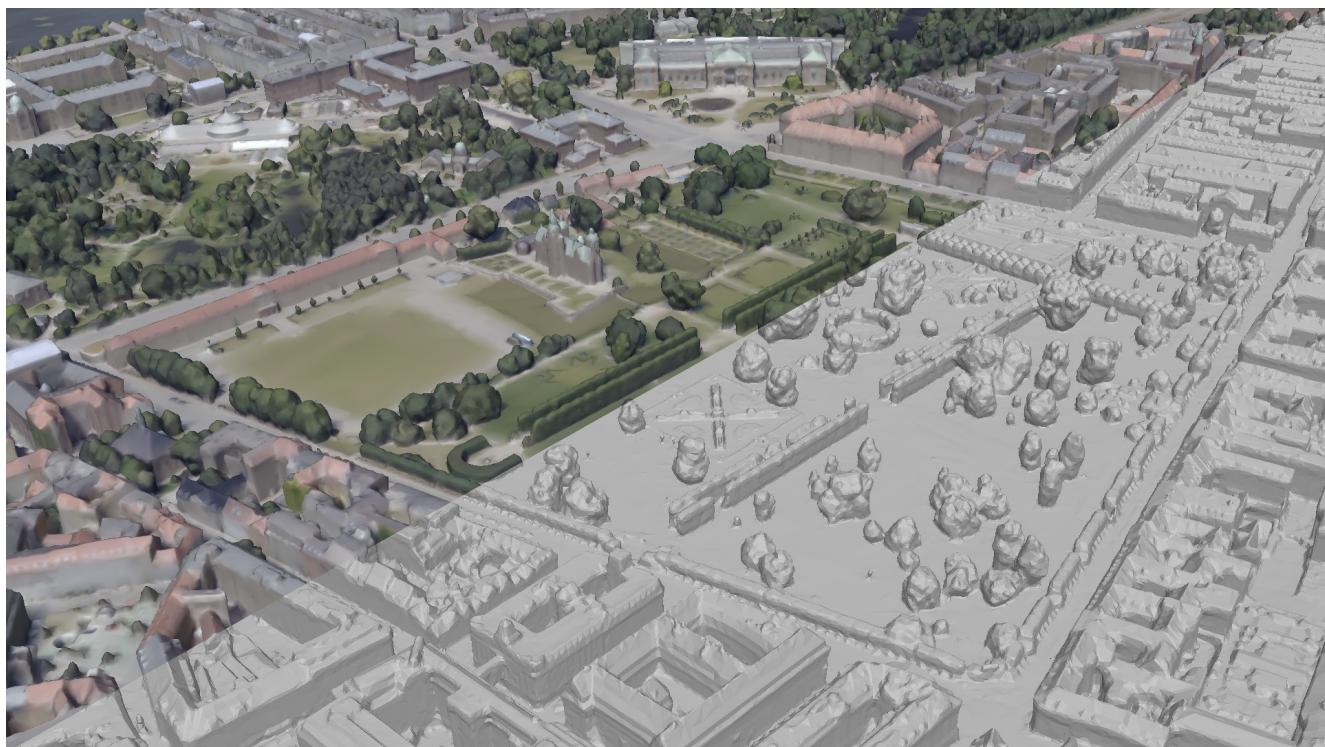


Figure 12. Rosenborg Castle closeup.

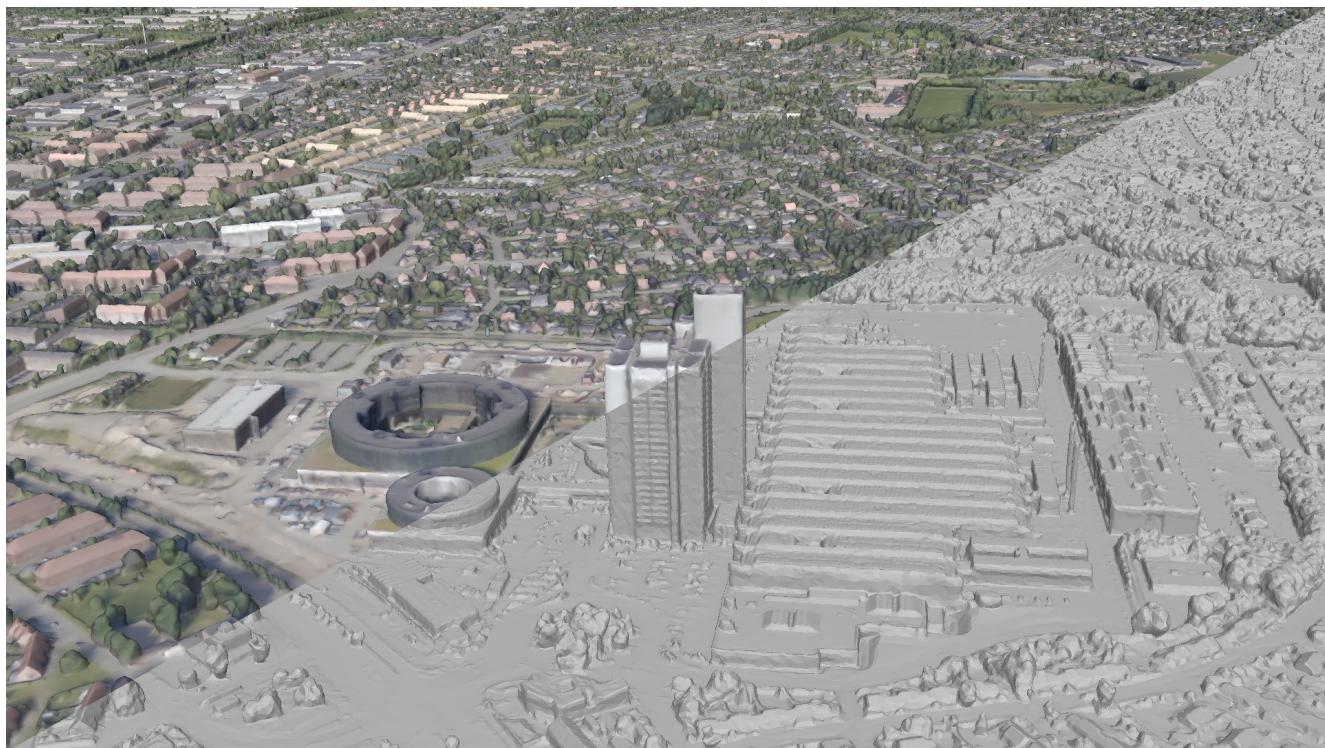


Figure 13. Herlev Hospital closeup.



Figure 14. AC Hotel by Marriott Bella Sky closeup.

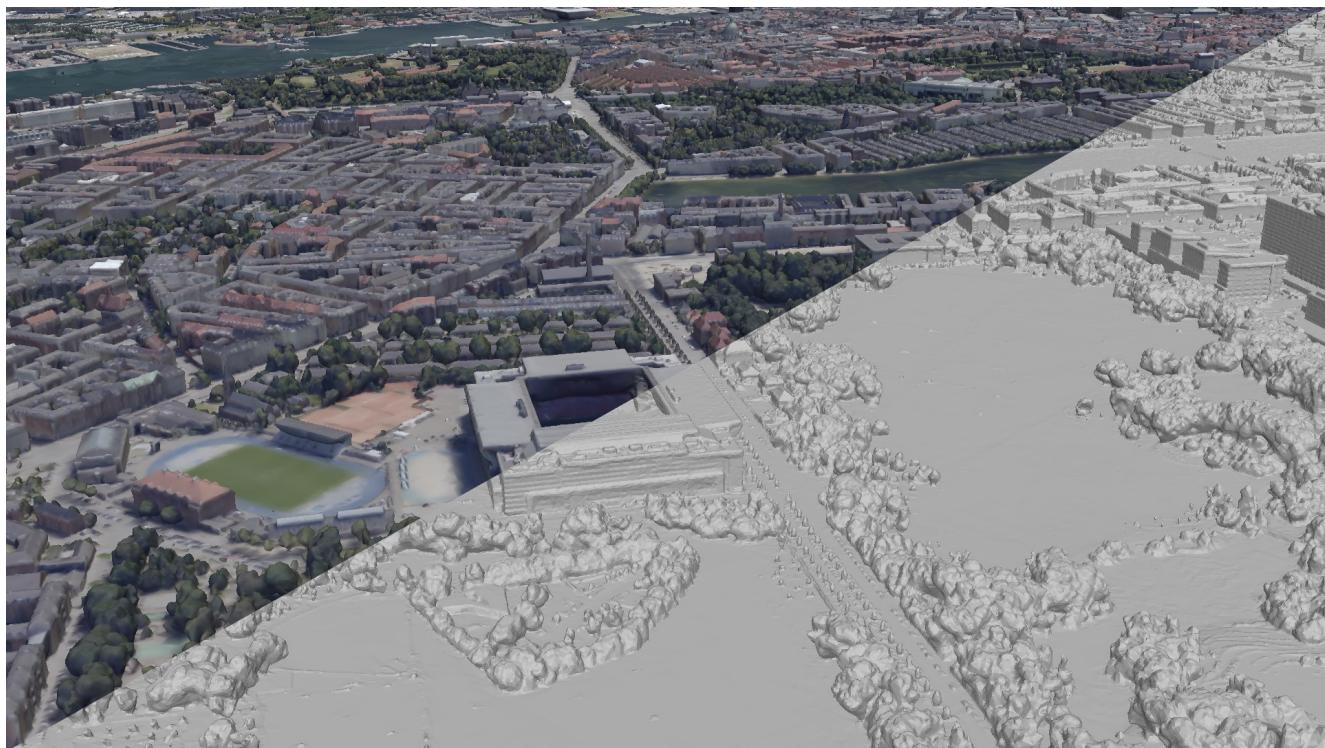


Figure 15. Telia Parken Stadium closeup.

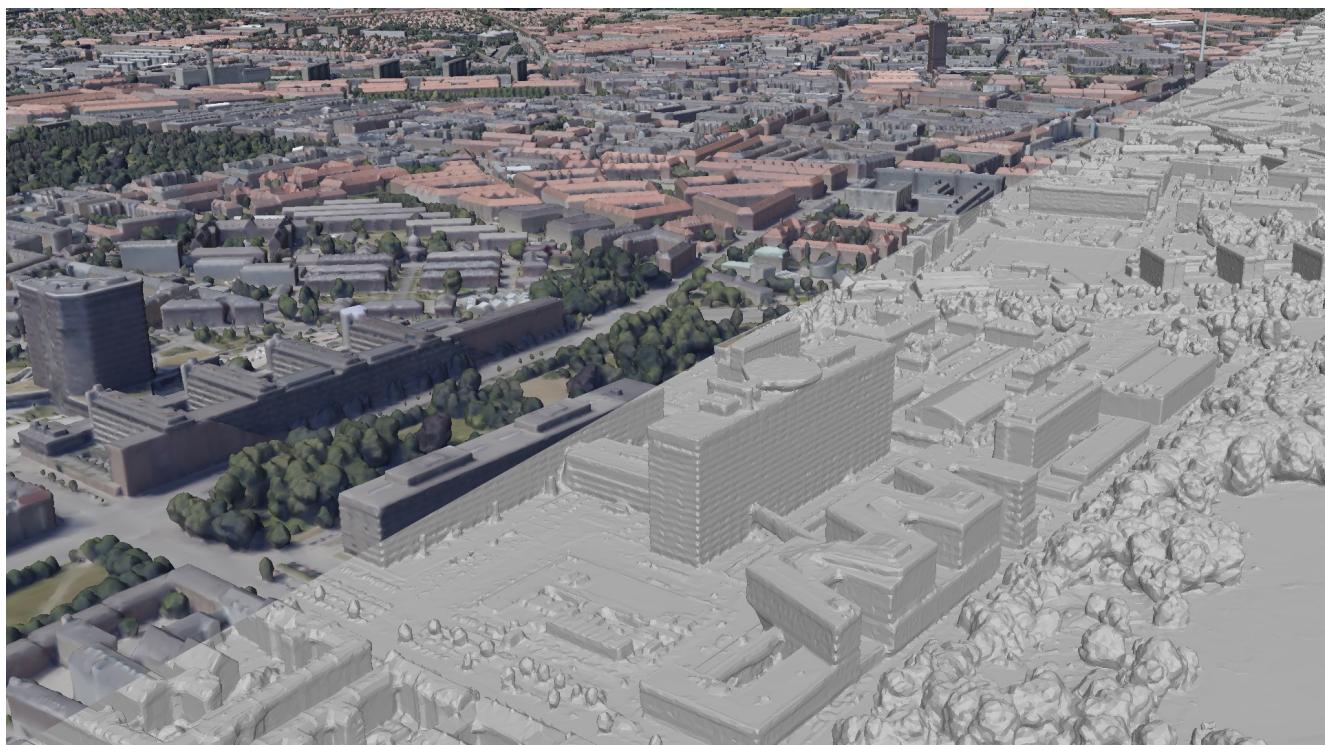


Figure 16. Rigshospitalet closeup.

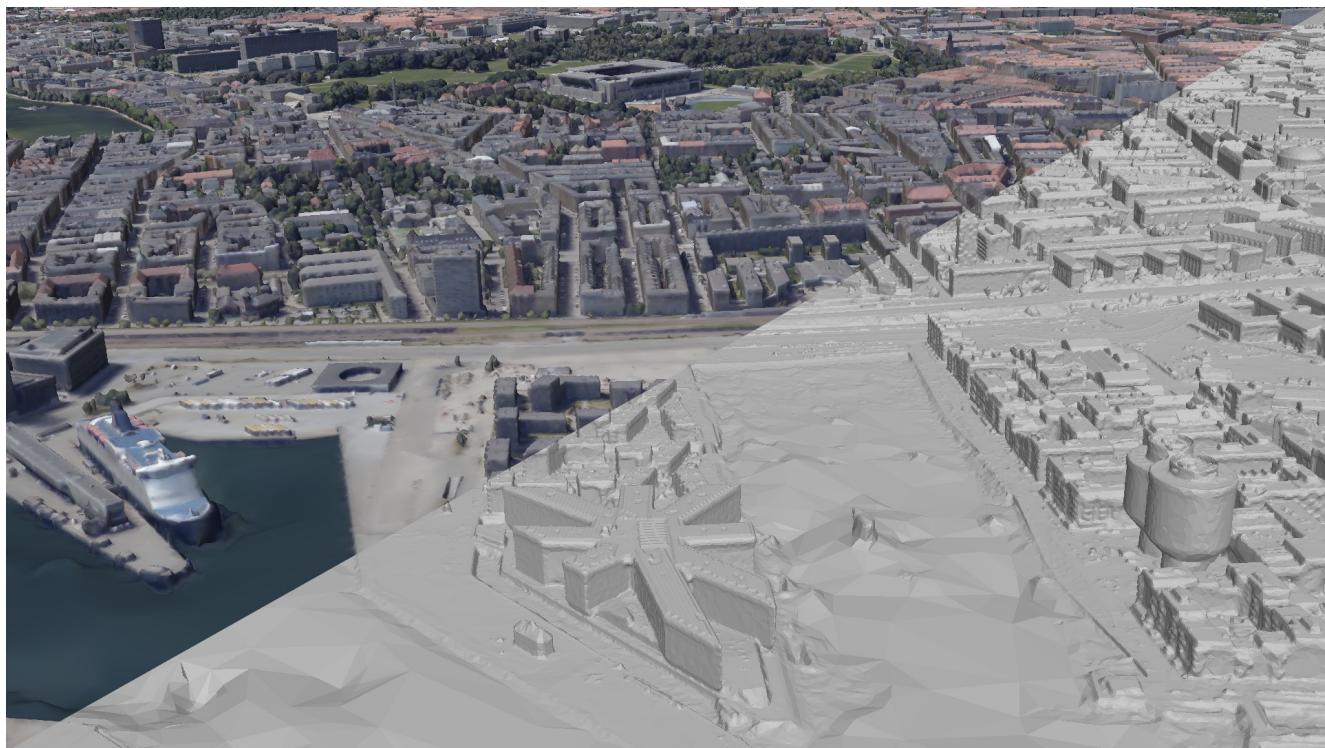


Figure 17. UN City closeup.

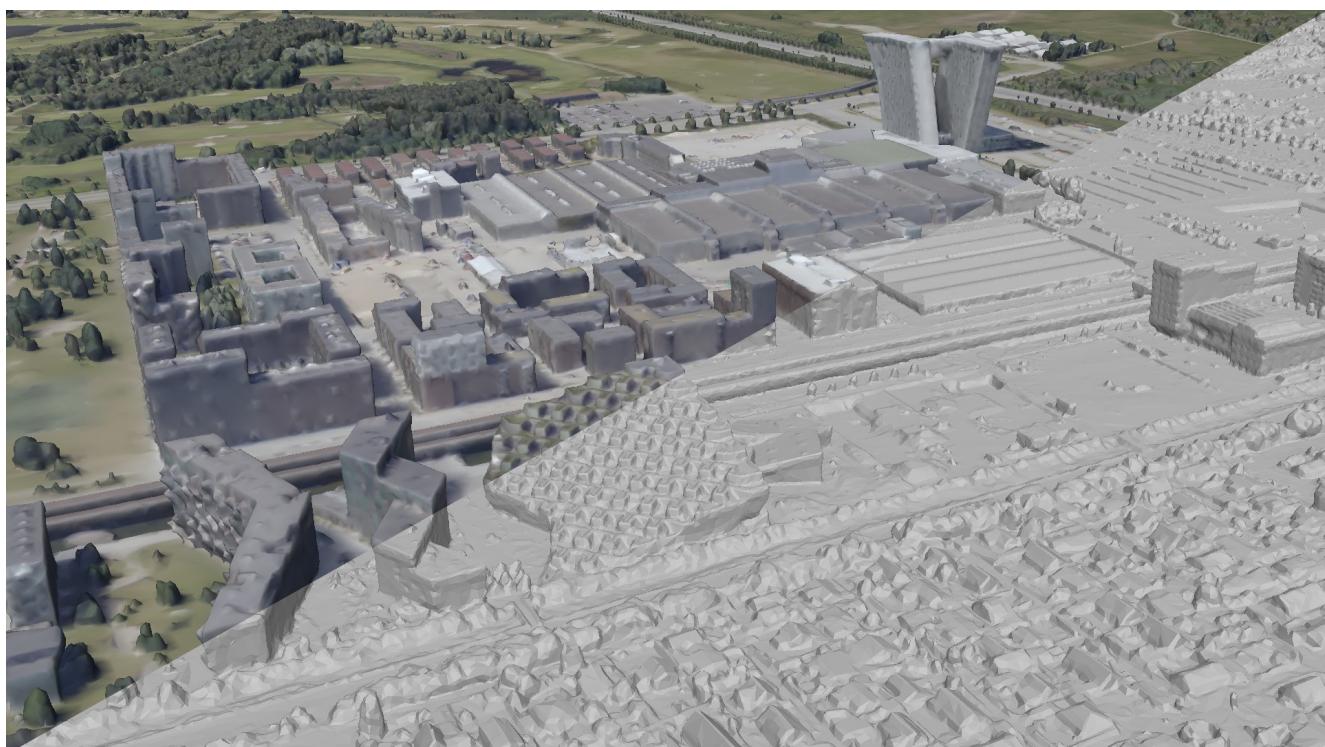


Figure 18. Mountain Dwellings closeup.

References

- [1] Danish Agency for Data Supply and Efficiency. Skraafoto of copenhagen, 2019. [1](#)
- [2] Heiko Hirschmuller. Stereo processing by semiglobal matching and mutual information. *IEEE Transactions on pattern analysis and machine intelligence*, 30(2):328–341, 2007. [1](#)
- [3] Google Maps. Copenhagen, Denmark, 55°40'33.95"N 1234'6.01"E, 2020. [1](#)