

Wärmebrückenerkennung in Drohnenbildern mit Deep Learning

Leipzig Data Week

HELMHOLTZ **AI**

The background features a dynamic, abstract design. It consists of two main color bands: a green band on the left and a blue band on the right. Within these bands are several white, translucent, wavy lines representing digital data or signals. Overlaid on the blue band is a complex network graph composed of numerous small blue dots connected by thin lines, forming a mesh-like structure.

Markus Götz

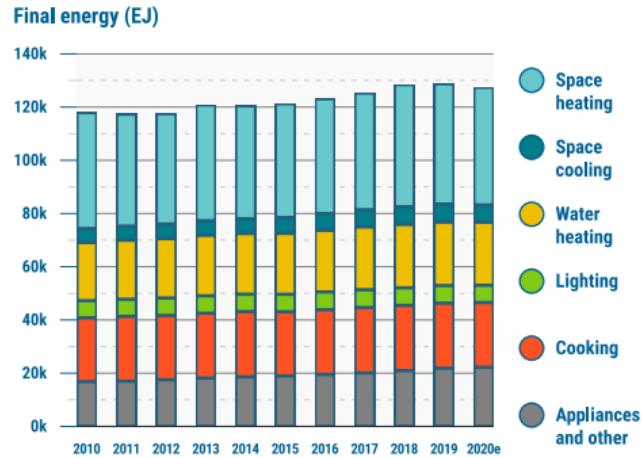
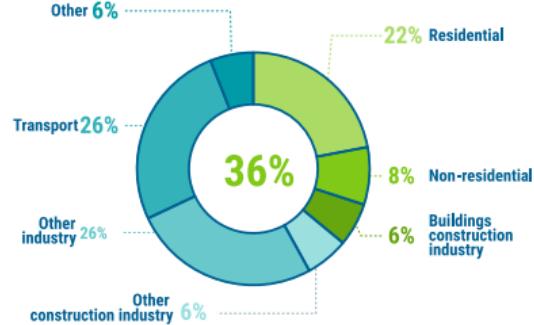
Scientific Computing Center (SCC), Karlsruher Institut für Technologie (KIT) / 2024-04-16

Was können Sie hier beobachten?



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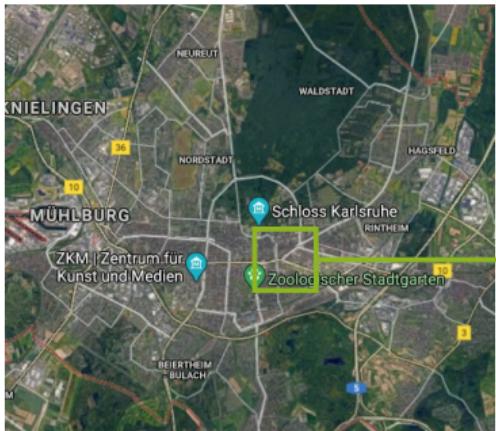
Energieverbräuche der Menschheit und Wärmebrücken



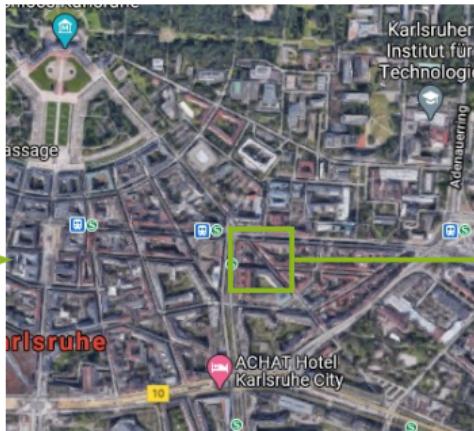
Quelle: United Nations Environment Programme (2021), Global Status Report for Buildings and Construction: Towards Zero-emission, Efficient and Resilient Buildings and Construction Sector, <https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction>

- Wärmebrücken sind Gebäudeteile mit erhöhtem Wärmetransport nach außen
 - Schimmelbildung, Verminderung der Gebäudelebensdauer, unangenehmes Wohngefühl

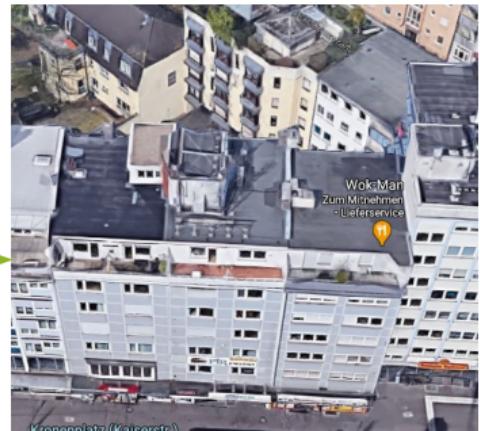
Energiequartiere und Quartierskonzept Karlsruhe



Stadtskale



Quartiersskale

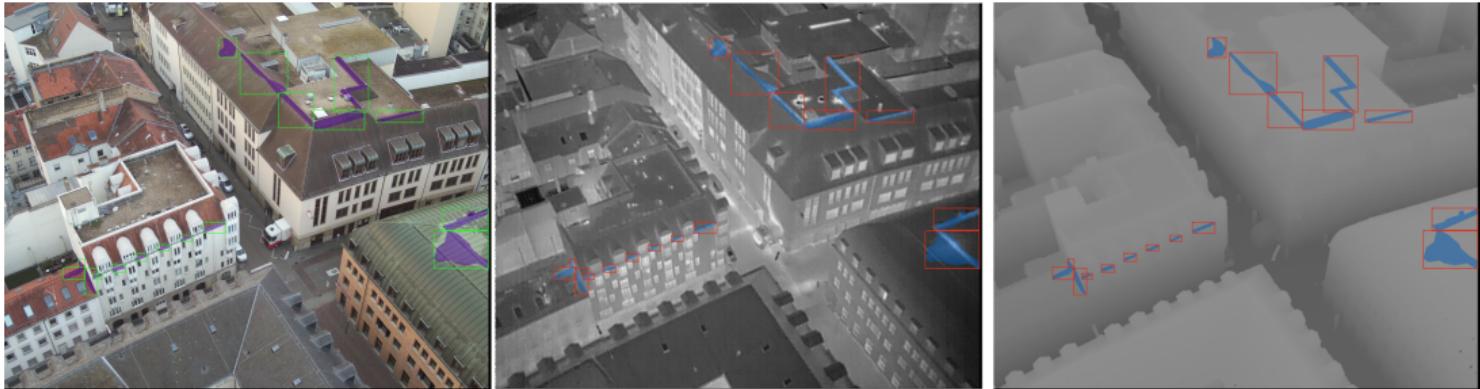


Gebäudeskale

- Ehrgeiziges Klimaschutzziel: bis 2050 CO₂-frei sein
- Betrifft Wohn- und Gewerbegebäuden sowie **kommunale Liegenschaften**
- **Thermische Sanierung** von Bestandsmasse

Thermal Bridges on Building Rooftops (TBBR)

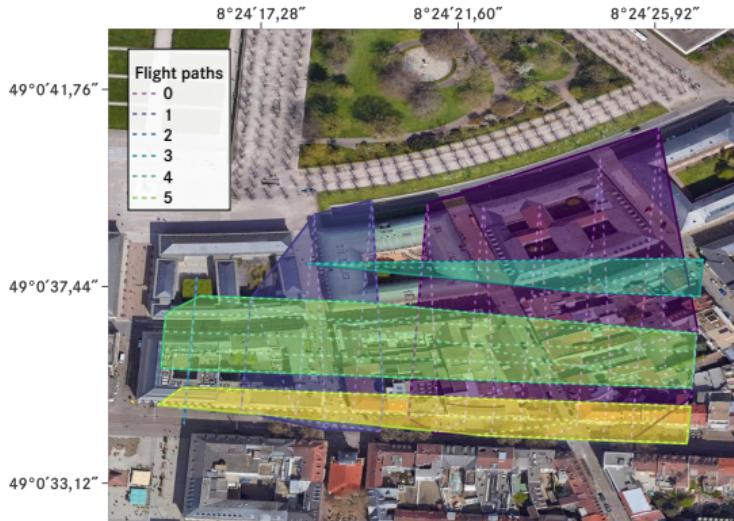
Der Datensatz



- **997 Drohnenbilder**, 2680×3370 Pixel Auflösung, **6927 Annotationen**
- 5 Informationskanäle → RGB, Wärme und Höhenfeld (RGBTH)
- Rund **70 GB** aufbereitete Daten
- CCBY 4.0 lizenziert, <https://zenodo.org/records/7022733>

Thermal Bridges on Building Rooftops (TBBR)

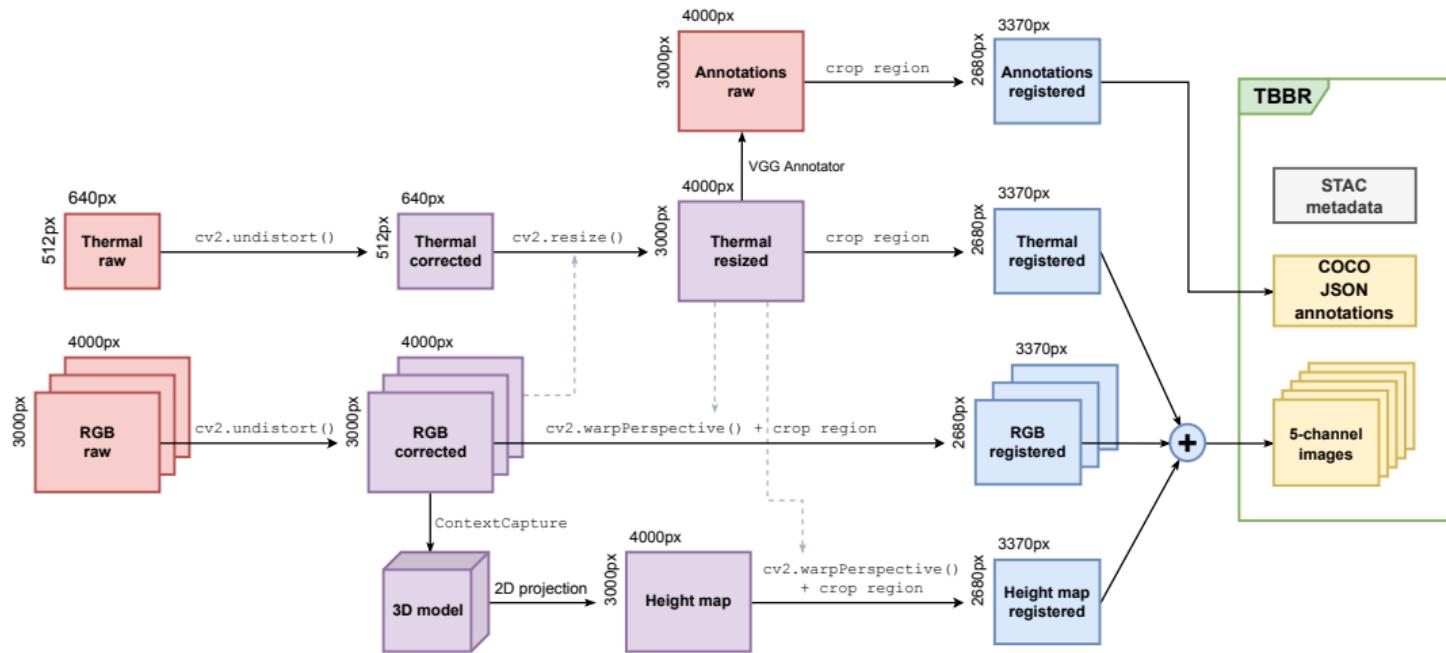
Datensammlung



- DJI M600 Drohne mit Zenmuse XT2 Kamera und FLIR Tau 2 Wärmesensor
- Wintermorgen, starke Wolkenbedeckung, Vermeidung anderer Strahlung
- Befliegung eines Innenstadtquartiers mit öffentlicher Bebauung

Thermal Bridges on Building Rooftops (TBBR)

Präprozessierung



Mayer, Z., Kahn, J., Götz, M., Hou, Y., Beiersdörfer, T., Blumenröh, N., Volk, R., Streit, A., & Schultmann, F. (2023). Thermal Bridges on Building Rooftops. *Scientific Data*, 10(1), 268.

Carnegie Mellon University

Automatische Wärmebrückenerkennung

Ergebnisse

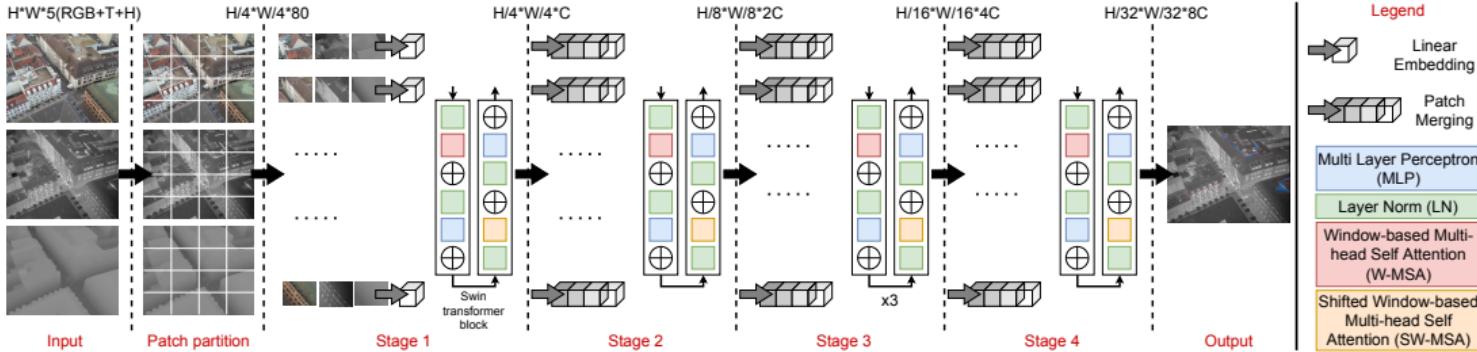
Architecture	Pretrained	Ablation	Energy (MJ)	Time (min)	AR@1	AR@10	AR@100	AR_m@100	AR_I@100
MaskRCNN R18*			20.5	205.5	0.060	0.169	0.169	0.119	0.250
MaskRCNN R18		✓	20.00 ± 0.20	205.3 ± 0.5	0.061 ± 0.002	0.165 ± 0.007	0.166 ± 0.006	0.129 ± 0.007	0.227 ± 0.010
MaskRCNN R18	✓		19.42 ± 0.10	199.7 ± 0.6	0.060 ± 0.005	0.170 ± 0.010	0.170 ± 0.010	0.130 ± 0.020	0.230 ± 0.010
MaskRCNN R50	✓		3.00 ± 0.03	39.5 ± 0.6	0.072 ± 0.008	0.270 ± 0.020	0.308 ± 0.008	0.270 ± 0.020	0.380 ± 0.010
MaskRCNN R50		✓	2.83 ± 0.01	35.6 ± 0.4	0.076 ± 0.008	0.310 ± 0.020	0.370 ± 0.010	0.350 ± 0.020	0.420 ± 0.010
MaskRCNN R50		✓	2.91 ± 0.03	38.1 ± 0.4	0.060 ± 0.010	0.260 ± 0.040	0.304 ± 0.007	0.280 ± 0.020	0.350 ± 0.020
MaskRCNN R50	✓	✓	2.74 ± 0.01	34.5 ± 0.4	0.068 ± 0.004	0.290 ± 0.030	0.360 ± 0.020	0.350 ± 0.020	0.400 ± 0.020
Swin-T			7.90 ± 0.10	125.3 ± 1.3	0.069 ± 0.003	0.239 ± 0.007	0.318 ± 0.004	0.290 ± 0.010	0.370 ± 0.010
Swin-T	✓		7.09 ± 0.03	107.3 ± 1.9	0.089 ± 0.006	0.380 ± 0.020	0.454 ± 0.007	0.430 ± 0.010	0.507 ± 0.007
TridentNet		✓	4.92 ± 0.08	57.7 ± 1.0	0.031 ± 0.003	0.140 ± 0.010	0.215 ± 0.007	0.160 ± 0.010	0.311 ± 0.010
TridentNet	✓		4.70 ± 0.10	51.9 ± 0.8	0.060 ± 0.010	0.210 ± 0.040	0.300 ± 0.050	0.220 ± 0.050	0.420 ± 0.070
FSAF			10.20 ± 0.09	103.7 ± 0.3	0.049 ± 0.008	0.150 ± 0.020	0.248 ± 0.008	0.223 ± 0.006	0.300 ± 0.010
FSAF	✓		10.00 ± 0.10	102.2 ± 0.3	0.070 ± 0.010	0.270 ± 0.020	0.380 ± 0.010	0.370 ± 0.020	0.410 ± 0.020

- **Intersection over Union (IoU; Jaccard):** misst Ähnlichkeit von Mengen
- **Recall (Sensitivität):** Metrik, die misst wie gut Modell positive Ergebnisse identifiziert

Mayer, Z., Kahn, J., Hou, Y., Götz, M., Volk, R., Schultmann, F. (2023). Deep learning approaches to building rooftop thermal bridge detection from aerial images. Automation in Construction, 146, 104690.

Automatische Wärmebrückenerkennung

Deep Learning Modell

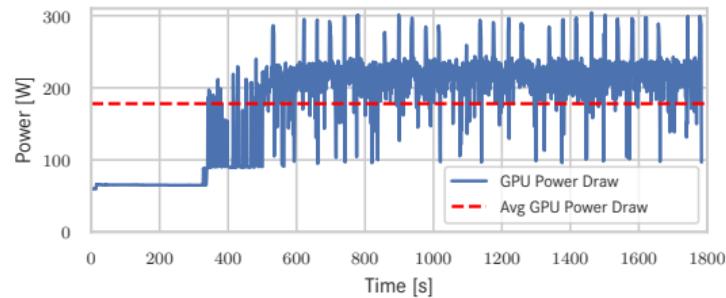


- Gewinner: vortrainierter Sliding WINdow Transformer (SWIN-T)
- Daten-paralleles Training auf $4 \times$ NVidia A100-40 GPUs
- Verwendet detectron2 und mmdetection Bibliothek
- BSD-3 lizenziert, <https://github.com/Helmholtz-AI-Energy/TBBRDet>

Automatische Wärmebrückenerkennung

Grüne KI: Energiemessungen

- Energieaufnahme von KI-Modellen zunehmen problematisch
- perun ermöglicht Energiemonitoring
 - On-board Sensorik
 - Performancecounter der Hardware
-  <https://github.com/Helmholtz-AI-Energy/perun>



$$E_{\text{total}} = PUE \cdot \sum_i^{\# \text{Knoten}} E_{\text{GPU}}^{(i)} + E_{\text{CPU}}^{(i)} + E_{\text{RAM}}^{(i)}$$

Debus, C., Piraud, M., Streit, A., Theis, F., & Götz, M. (2023). Reporting electricity consumption is essential for sustainable AI. *Nature Machine Intelligence*, 5(11), 1176-1178.

Ausblick

