Analysis of the applicability of super-resolved Sentinel-2 images for segmentation of photovoltaic power plants

Fraunhofer EMI

Fraunhofer-Institut für Kurzzeit-dynamik, Ernst-Mach-Institut, EMI

Pauline Hecker[1], Hannes Bäuerle[1], Frank Schäfer[1]

[1] Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI

Motivation

The emergence of big data and advancements in image processing, combined with new generations of Earth Observation (EO) satellites, have resulted in an abundance of EO data for scientific and practical applications. This surge of EO datasets is driving the development of novel applications, catalyzing long-term business opportunities. The combination of extensive earth observations with sophisticated modelling enhances the ability to analyze and understand Earth's systems, supporting scientific research and aiding decision-making. Although commercially available EO data can offer high spatial resolutions, they are often expensive and limited in temporal availability, prompting researchers to explore alternative methods. This is particularly evident in the renewable energy sector, where precision and efficiency are crucial.

The expansion of renewable energy is essential to achieving climate change targets. To optimize the usage of solar radiation, it is imperative that photovoltaic systems function consistent and reliable. As a result, research into monitoring these systems is vital. Ground-based monitoring using sensors or human labor in remote or large facilities is costly and time-consuming. However, remote sensing data offers significant opportunities such as long-term availability, complimentary access to certain datasets and large spatial coverage. Therefore, the aim of this study is to analyze the applicability of super-resolution techniques for detection and segmentation of photovoltaic (PV) power-plants.

Approach

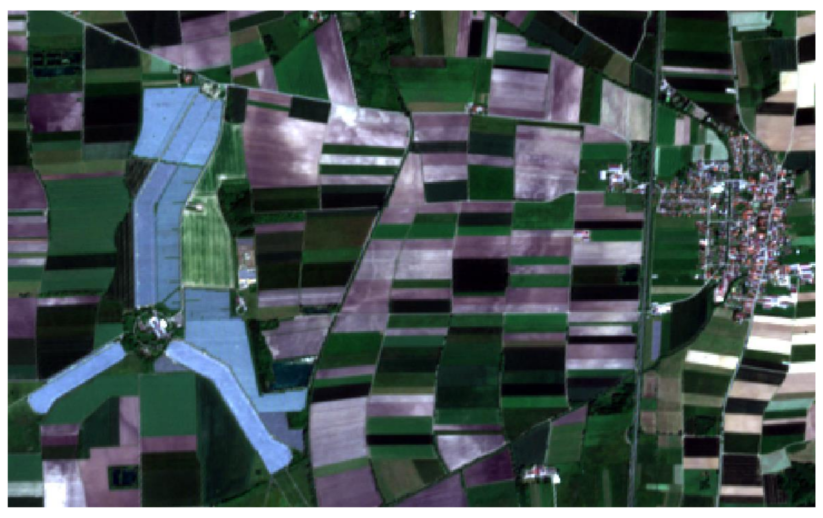
Model Training

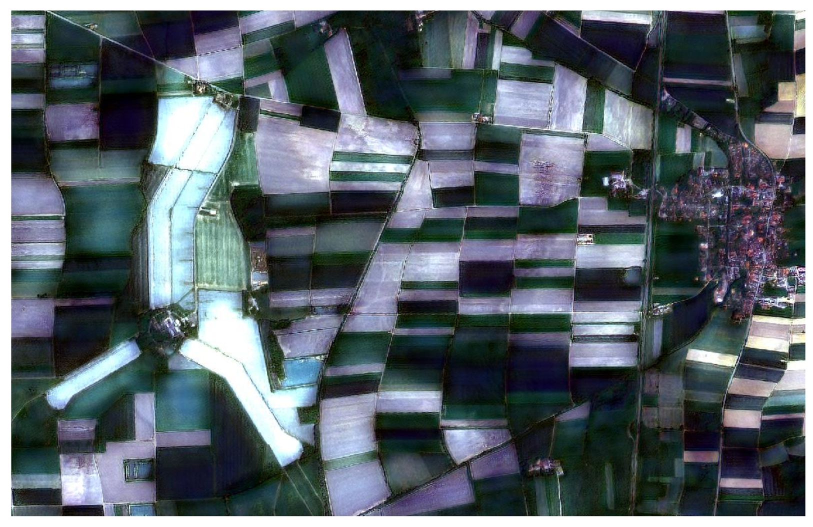
The pretrained model employed in this study is based on Ledig et al.[1] who introduced a super-resolution generative adversarial network (SRGAN) and was modified by Cresson[2]. The model considers the characteristics of remote sensing images such as multispectral measurements and higher bit-depths. For training 250 SPOT-6 and SPOT-7 images captured across France mainland from March to October 2020 were used. The high-resolution (HR) images were pansharpened from 6m to 2.5m to reach a 4x resolution factor. Around 150k image patches were generated from the input images to train the model. The model is trained with the four channels of SPOT-6/7 instrument (i.e., red, green, blue, NIR). As low-resolution input, Sentinel-2 images captured around the same date as the HR-equivalent are used.

A second convolutional neural network (CNN) is trained for segmentation of PV-plants. As input data, HR images (0.8m) from Geofen-2 and Beijing-2 constellation is used. Jian et al.[3] prepared an open-source dataset of labeled PV-facilities images.

Results and Discussion

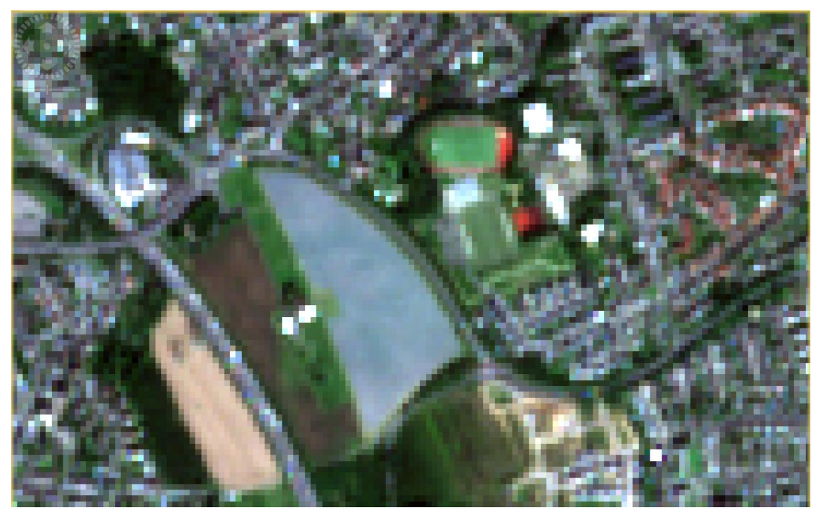
The applied model results in a 4x super-resolved Sentinel-2 image. The output image demonstrates a notable enhancement in detail in straight lines, e.g., streets and agricultural boundaries. Human settlements are more defined but show some unrealistic textures. Also, there is a clear change in the color, which also affects indices such as NDVI that could be used in further analysis to detect photovoltaic power plants.





Above and below: Sentinel-2 input image

Above and below: Sentinel-2 super-resolved output



Segmentation input image

Segmentation input label image

Segmentation result

Segmentation model results show partially detected photovoltaic pixels. Detected rows are finer than in the corresponding labeled image which shows potential for improvement of the model. A large majority of pixels is wrong classified.

Conclusion

Initial findings indicate an enhancement of spatial resolution of Sentinel-2 images. Using a pretrained model for super-resolution, future research will focus on refining this model and set up an adapted architecture for resolving images of photovoltaic power plants. For further analysis, the model will be trained with more images containing photovoltaic powerplants.

The pixelwise segmentation model using a deep convolutional neural network shows the potential for future fault detection tasks. Though, the model needs refinement in its architecture for differentiating PV-labeled pixel from non-PV-labeled pixel.

Contact

Pauline Hecker
Geoanalysis
Tel. +49 761 27140 424
pauline.hecker@emi.fraunhofer.de
Fraunhofer EMI
Ernst-Zermelo-Straße 4
79104 Freiburg im Breisgau
www.fraunhofer.de

1 Ledig, C., Theis, L., Huszar, F., Caballero, J., Cunningham, A., Acosta, A., Aitken, A., Tejani, A., Totz, J., Wang, Z., & Shi, W. (2016, September 15). Photo-Realistic Single Image Super-Resolution Using a Generative Adversarial Network. https://arxiv.org/pdf/1609.04802.pdf
2 Cresson, R. (2022). SR4RS: A Tool for Super Resolution of Remote Sensing Images. Journal of Open Research Software. https://openresearchsoftware.metajnl.com/articles/369/files/submission/proof/369-1-5702-1-10-20220302.pdf
3 Jian, H.; Yao, L.; Nu, N.; Qin, J.; Liu, T.; Liu, Y.; Zhou, C. (2021): Multi-resolution dataset for photovoltaic panel segmentation from satellite and aerial imagery. In: *Earth System Science Data*. DOI: 10.5194/essd-13-5389-2021.