Investigating Generalized Strategy for Single-Image Satellite Super-Resolution Using Deep Learning

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The effectiveness of remote sensing applications is critically influenced by image quality, which can be constrained by factors such as resolution, environmental conditions, and sensor-specific artifacts. Super-resolution (SR) is a fundamental computer vision task and an ill-posed inverse problem focused on enhancing the spatial resolution of images. It encompasses traditional approaches such as interpolation techniques, wavelet transformations, and sparse representation, as well as modern deep learning-based methods. SR methods typically rely on paired low- and high-resolution (LR and HR) images, where LR images are generated through bicubic downsampling of HR images. While effective on the data distribution they are trained on, these methods struggle to generalize to datasets outside the training distribution due to domain gaps between different sensors and ground sample distances (GSDs), necessitating retraining for new data (2).

In this paper, we extend our previous work (1) by demonstrating the effectiveness of super-resolution on Sentinel and similar low-resolution satellite images from RGB and multispectral sensors. The uniqueness of our approach lies in the fact that it was trained exclusively on high-resolution aerial and satellite images with GSD under 1.5 meters, yet still performs well on low-resolution images. This is made possible by the nature of the method itself, which was designed for generalized image enhancement across a variety of data sources. We use U2D2 (1), our prior framework for generalized enhancement, which was initially developed to enhance high-resolution aerial and satellite images with GSDs below 1.5 meters.

The U2D2 framework utilizes a modular approach, where a deep learning-based upsampler (DLU) first performs SR and mitigates common degradations such as noise, blur, compression artifacts, and aliasing by simulating LR images during training. The upsampled images are then processed by a diffusion-based refinement module, which sharpens the image and recovers details from the original LR input. This pipeline not only produces visually improved images, but also enhances downstream applications like object detection and building/road segmentation. Our results demonstrate that the framework works effectively across a range of sensors and GSDs (from 10 cm to 1.5 m), and notably, it can super-resolve Sentinel-2 and similar low-resolution satellite images by up to 4×, from 10 m GSD to 2.5 m GSD , without requiring retraining for new sensors or GSDs.

In the presentation, we would like to showcase the SR results for various low-resolution satellite image and compare them to other state-of-the-art methods. Our results demonstrate that our approach produces high-quality, natural-looking super-resolved images, offering substantial improvements in visual quality and performance for remote sensing applications. Our approach demonstrates how a modular framework can provide a scalable and robust solution for the enhancement of low-resolution satellite imagery, extending its applicability to RGB and multispectral bands. Such an approach has significant implications for remote sensing applications, enabling more accurate environmental monitoring, urban planning, and agricultural analysis, especially in scenarios constrained by limited resolution. By addressing domain gaps and offering a generalized solution, this work paves the way for broader adoption of SR techniques in remote sensing workflows.

References

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