Technik & Architektur
Master of Science in Engineering
Photonics and Laser engineering

Master-Thesis Photonics and Laser engineering

Pore space exploration with multi-scale X-ray computed tomography

Super-Resolution methods in X-ray Computed Tomography

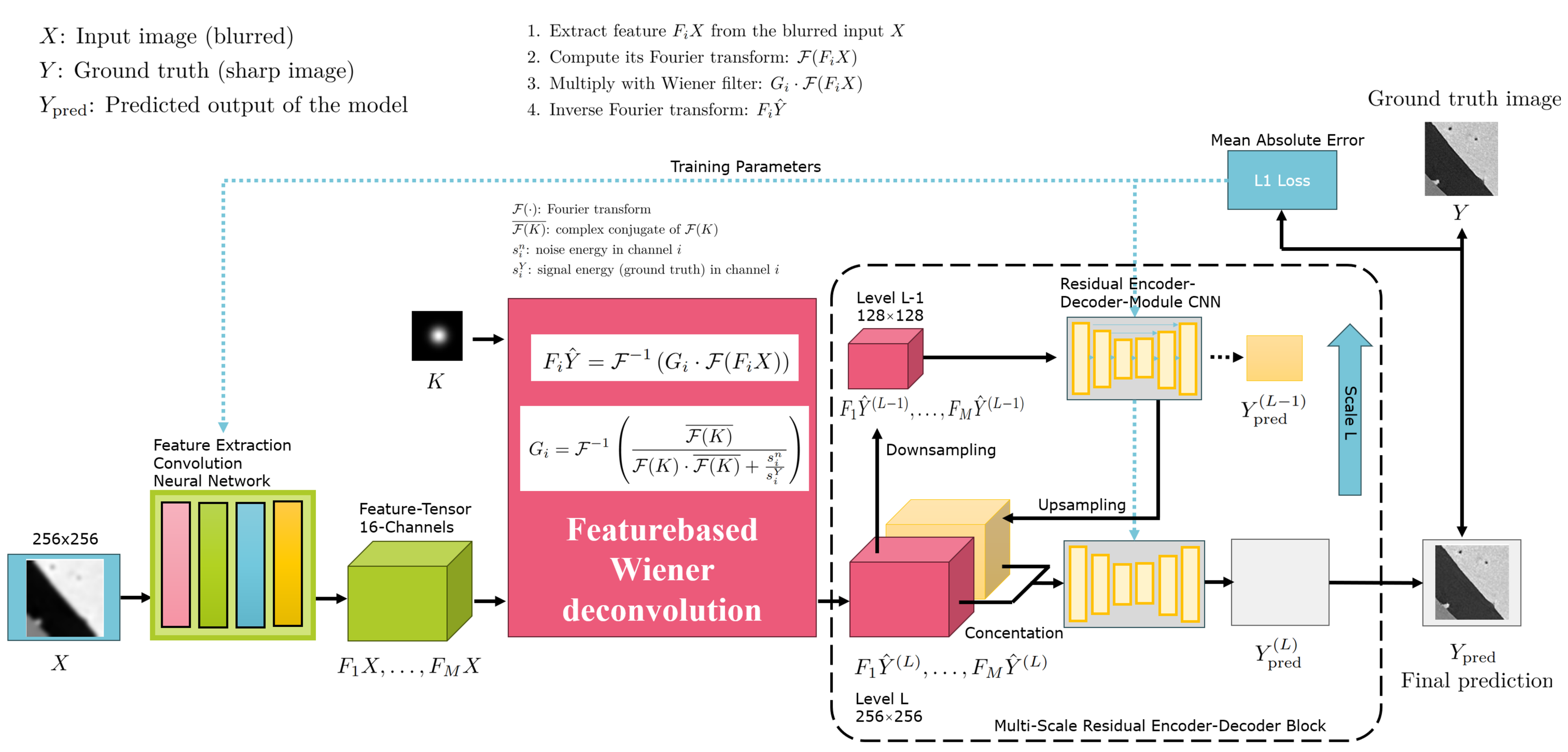

Fig. 1: Architecture of the Deep Wiener Deconvolution Network

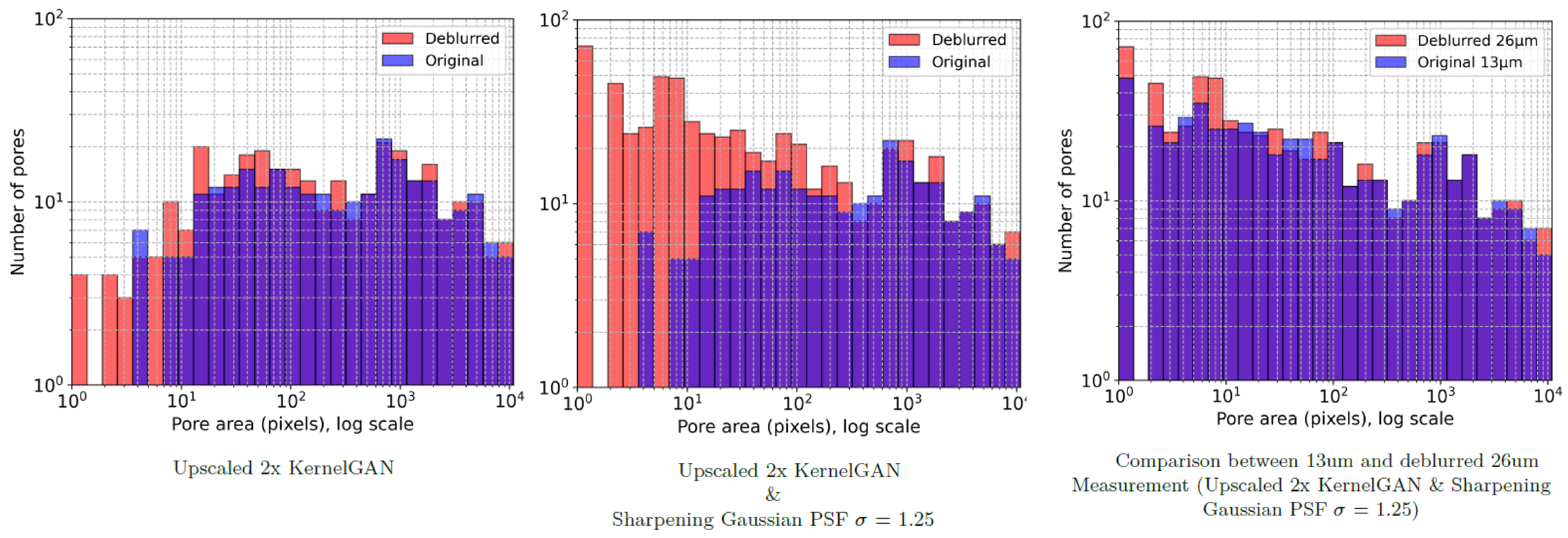

Fig. 2: Quantitative evaluation of pore segmentation on real CT data.
Left: Upscaled 2× using KernelGAN only.
Center: Upscaled 2× using KernelGAN with additional sharpening (Gaussian PSF, σ = 1.25).
Right: Comparison of deblurred 26 µm data with original high-resolution 13 µm scan.

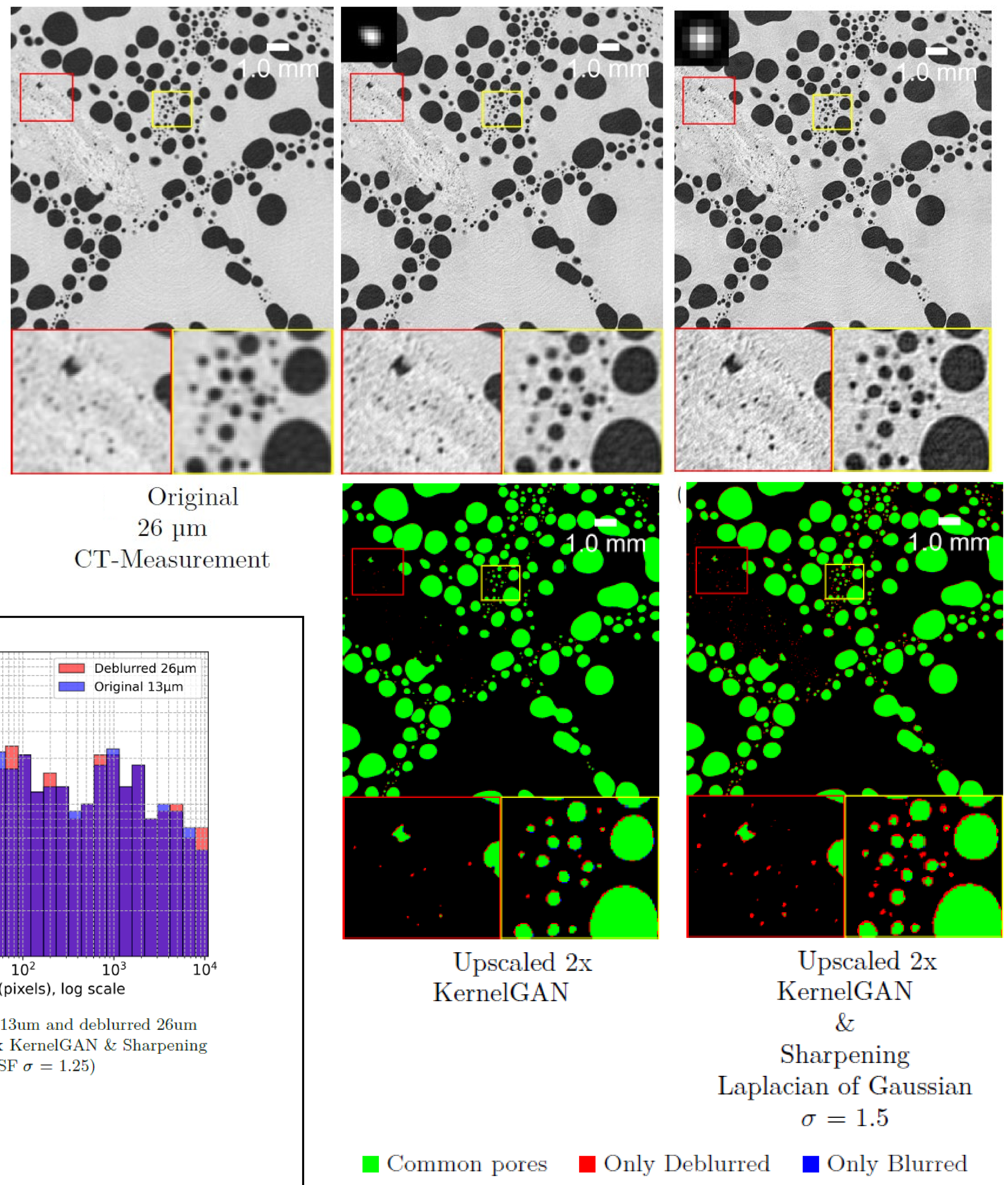

Fig 3: Visual comparison of upscaling and sharpening strategies on real CT data

Introduction

In the analysis of porous materials with computed tomography (CT), resolution is a critical factor for detecting fine pore structures. However, high-resolution CT scans are often associated with long acquisition times, increased image noise, and a limited field of view. This presents a particular challenge for the quantitative analysis of small pores or densely connected structures. Conventional inter-polation or sharpening methods typically fall short, as they do not enable true reconstruction of not-perceivable image content. Therefore, there is a need for robust methods that can specifically enhance image details and segmentability, even under constrained scanning conditions.

Materials and Methods

This work investigates a hybrid approach that combines physics-based deconvo-lution with data-driven learning. The Deep Wiener Deconvolution Network (Fig. 1) integrates classical Wiener filter theory into a trainable deep network with multi-stage residual architecture. For real CT data lacking high-resolution ground truth, KernelGAN was employed as an unsupervised method to estimate image-specific point spread functions (PSFs). The training data were based on synthetically generated blur using controlled Gaussian kernels and down-blur-up procedures to simulate realistic degradation.

Results

In synthetically blurred images, the Deep Wiener Deconvolution Network was able to detect up to 70% more pores under moderate Gaussian blur compared to the unprocessed input, including structures as small as 1–3 pixels (Fig. 2 and Fig. 3). Otsu-based segmentation showed close agreement with the ground truth, particularly for small to medium-sized pores (1–100 pixels). For real CT datasets, where the PSF was estimated using Kernel-GAN, visible improvements were achieved: complex pore networks with narrow connections became more distinguishable, and line profile analyses confirmed a significant increase in edge sharpness. The method thus demonstrates strong potential for reliable post-processing in CT-based pore analysis, though it remains naturally limited in cases of severe information loss due to heavy blurring.

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