

## **Super-Resolution Using Unsupervised Deep Internal Network**

(No. T4-1850)

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## **Overview**

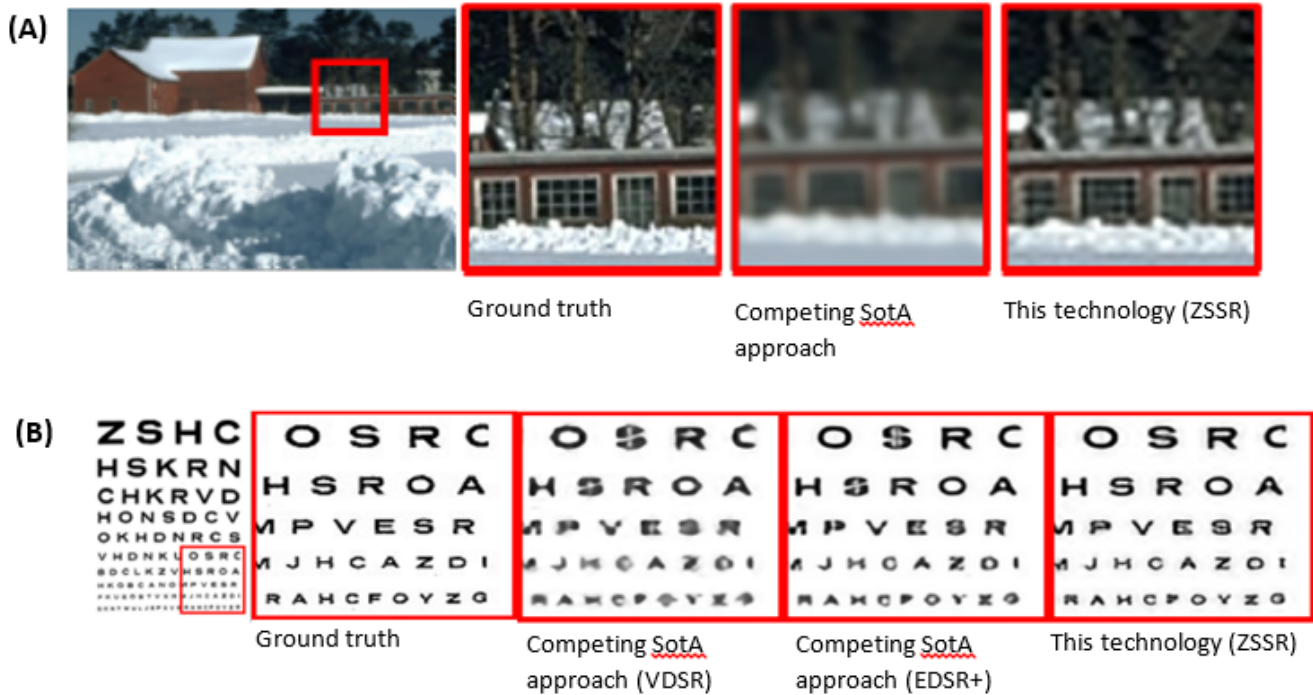
Optical and dimensional limitations of images can be partially overcome today using signal enhancement technologies which typically rely on supervised, deep-learning methods. However, as existing methods are restricted to specific training images and distortion types, they provide poor results for any practical case, unless huge set of data-pairs exist and all share the same exact distortion type. The current invention enables signal enhancement of low-resolution images, by exploiting deviations from expected internal patch recurrences detected within the image itself. More specifically, the approach leverages cross-scale internal repetition of image-specific information, which is trained, at test time, on internal examples extracted solely from the test image. This first unsupervised conventional neural network (CNN)-based super-resolution approach allows for signal enhancement of real-world images acquired under suboptimal, unknown or image-specific conditions and has been shown to outperform state-of-the-art technologies.

## **The Need**

Signal enhancement of corrupted input collected under suboptimal conditions, poses multiple challenges, including super-resolution, denoising, deblurring, dehazing and lens artifact correction. While deep-learning techniques have dramatically improved super-resolution performance, they remain limited to specific, high-resolution training data, free of distracting artifacts. For single-image enhancement that does not obey ideal conditions, these limitations demand lengthy and exhaustive training on external databases and strict fulfillment of the training conditions to obtain satisfactory results.

## **The Solution**

This invention introduces zero-shot super-resolution (ZSSR), which exploits deep-learning methodologies, without requiring any prior image or training data. The internal recurrence of data within the single input image is exploited for on-line training of a small image-specific convolutional neural network (CNN) in examples extracted from the low-resolution image itself. The method bears no recurrence patch-size limitation, enabling adaptation of the CNN to different settings for the same image, and requires no external information or prior training. This unsupervised CNN-based super-resolution method has been shown to substantially outperform externally trained state-of-the-art super-resolution of suboptimal, low-resolution images (Figure A). In cases of ideal imaging conditions, the ZSSR output proved competitive to that of state-of-the-art supervised methods (Figure B).



A) Super-resolution of a suboptimal low-resolution image using the ZSSR approach versus state-of-the-art (SotA) approaches.

B) Super-resolution using ZSSR as compared to state-of-the-art methods, of a low-resolution image generated under ideal, supervised conditions.

## Applications and Advantages

### Advantages

- Suitable for a wide range of images and data types
- Applicable for images of any size and any aspect ratio
- No pre-training requirement
- Adaptable to images with known or unknown imaging conditions
- Time-effective training
- No requirement of side information/attributes
- No requirement of additional images

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### Applications

- This invention can be applied in a range of images and distortion types requiring enhancement, including:
- Single video sequences
- Old photos
- Noisy images
- Biological data
- Medical images (e.g., fMRI)
- Audio sequences

## Development Status

The image-enhancement platform has been demonstrated effective for super-resolution, dehazing, watermark removal and image defect elimination ([link to project web-page \[1\]](#)). Ongoing work is optimizing the technology for fMRI image applications. A patent application has been submitted.

## Market Opportunity

This innovation can be of commercial relevance in a wide range of markets reliant upon imaging technologies, including:

- Consumer image processing software programs
- Military and security
- Medical imaging
- Microscopy and other lab imaging

## Patent Status

USA Granted: 11,907,835

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