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XXXIII Cycle

Deep Neural network for Super-resolution of Multitemporal images

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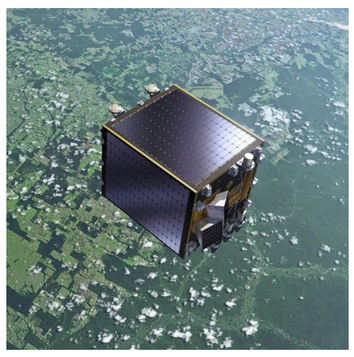
Research context and motivation

- Remote sensing is playing an increasingly important role in mapping and monitoring the Earth.
- Super-resolution allows to increase the availability of high spatial resolution remote sensing data and it is crucial for many applications.

- The approaches to image super-resolution (SR) falls into two categories:
  - single-image SR (SISR): LR to HR
  - multi-image SR (MISR): LRs of the same scene to HR

- Generally MISR works are based on simulated data: HR → LRs.
- The PROBA-V satellite is an Earth observation satellite designed to map land cover and vegetation growth across the entire globe:

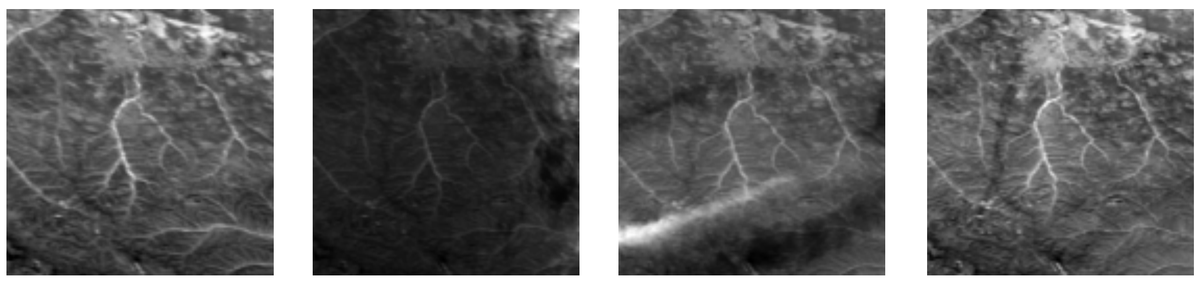


- delivers **real LR and HR images** captured by the same platform at multiple times

- Its unique nature enables data-driven methods such as CNNs to learn the inversion of possibly **complex degradation models**.

Addressed research questions/problems

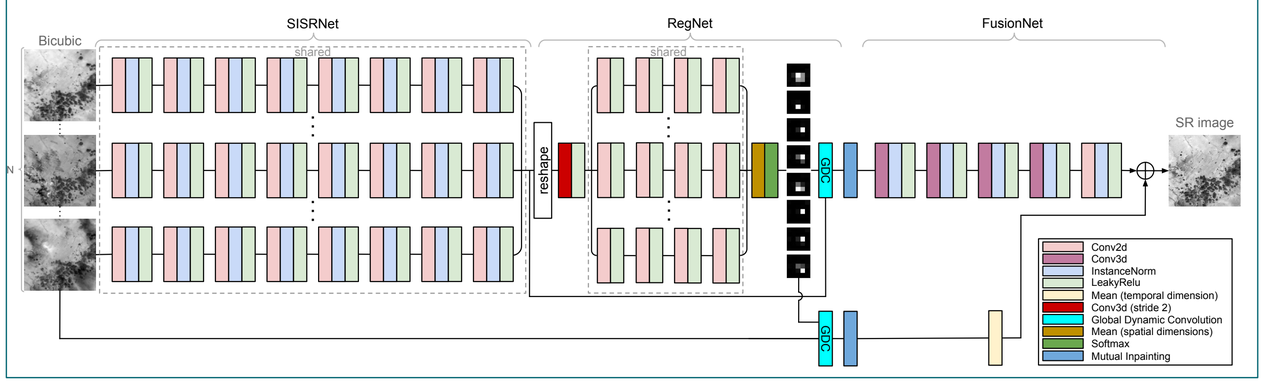
- MISR extensively applied on remote sensing images, but very little work with deep learning.
- Most of the works in literature simulate LR images by degrading and downscaling HR images. This is a simplified scenario assuming a non-blind problem where the sensor imaging model is known a priori.
- The vast majority of deep-learning MISR methods in literature compensate for the motion as a preprocessing step.



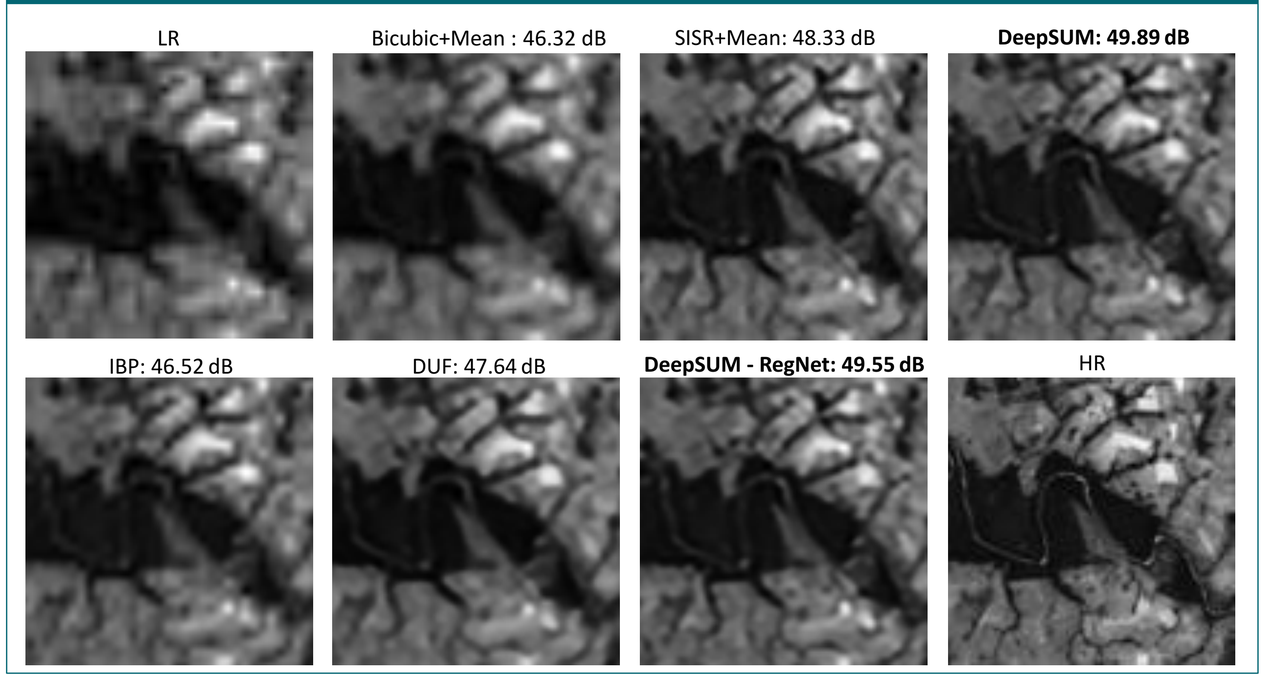
- LR images and the corresponding HR image are taken over a long period of time:
  - Brightness (weather, changes in the landscape)
  - Dissimilarity across LR images
  - Geometric disparity (translational shifts)

Adopted methodologies

- **The proposed residual CNN exploits both spatial and temporal correlations in the low-resolution image set by using 3D convolutional layers to combine multiple images from the same scene.**
- N LR images bicubically interpolated images are then fed into the CNN architecture:
  1. **SISRNet**, subnetwork aiming to perform a SISR task where each of the N images is processed independently by a sequence of 2D convolutional layers (create a **high-dimensional feature** space suitable for downstream tasks)
  2. **RegNet**, subnetwork proposing registration filters from the high-dimensional features
  3. **FusionNet**, aims to merge the image representations in the feature space by exploiting a sequence of 3D convolutional layers.
- **Pretrain** SISRNet and RegNet separately with a task-specific objective
- **Finetune** everything with the super-resolution objective (modified MSE embedding an absolute brightness correction and a shift correction between SR and HR image)

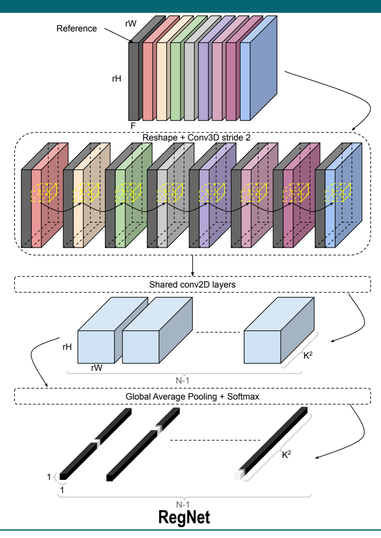


Results



Novel contributions

- A novel CNN-based architecture, called **DeepSUM**, to combine multiple unregistered images from the same scene exploiting both spatial and temporal correlations
- This method includes image registration inside the CNN architecture, as a subnetwork named **RegNet**, which dynamically computes custom filters and applies them to higher dimensional image representations.
- DeepSUM tackles the MISR problem on satellite images by **jointly registering** the input LR images and reconstructing the SR image, all within an **end-to-end trainable** CNN, where the two tasks are optimized jointly.



Future work

- **SISRNet** based on non-local models:
  - recent work on extending convolutional layers to include non-locality. e.g., by using graph-convolutional architectures, a kind of convolution that draws from ideas in graph signal processing

Submitted and published works

- Bordone Molini, A. , Valsesia , D., Fracastoro, G. and Magli, E., "*Deep learning for super-resolution of unregistered multi-temporal satellite images*", 10th Workshop on Hyperspectral Images and Signal Processing: Evolution in Remote Sensing (WHISPERS), 2019, pp. 125-129
- Bordone Molini, A. , Valsesia , D., Fracastoro, G. and Magli, E., "*DeepSUM: Deep neural network for Super-resolution of Unregistered Multitemporal images*", IEEE Transactions on Geoscience and Remote Sensing, Major Review

List of attended classes

- 01SHBRP - Examples of graph optimisation models in management science (didattica di eccellenza)(19/01/2018, 4)
- 01SHCRV - Unsupervised neural networks (didattica di eccellenza) (09/04/2018, 6)
- 01QORRV - Writing Scientific Papers in English (21/03/2018, 4)
- 01RELKG - Probabilità applicata e machine learning (03/09/2018)
- 01RISRP - Public speaking (21/07/2019, 1)
- 02LWHRP - Communication (21/07/2019, 1)
- 01SWPRP - Time management (21/07/2019, 1)
- 01SYBRP - Research integrity (24/07/2019, 1)
- 01RONKG - Python in the Lab (20/09/2019, 4)

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