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## Tutor: Giuseppe Ruello

### XXXIII Cycle - II year presentation

# Deep Learning for Remote Sensing Applications

The twin **Sentinel-2** satellites ensure a **global World coverage** with a revisit time of **five days** at the equator, providing a multi-resolution stack composed of **13 spectral bands**, between the visible and short-wave infrared (SWIR), distributed over three resolution levels. The **10 and 20 m** bands are commonly employed for land-cover or water mapping, agriculture or forestry, estimation of biophysical variables, and risk management. In light of its **free availability** and its above remarked **wide applicability**, some methods are proposed to super-resolve Sentinel-2 images, rising 20 m up to 10 m resolution, and some applications are investigated to validate the goodness of these methods.

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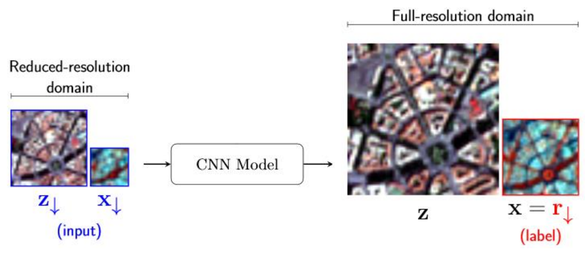
## FUSE

## *Fast Upscaling of SEntinel-2*

### Main Idea

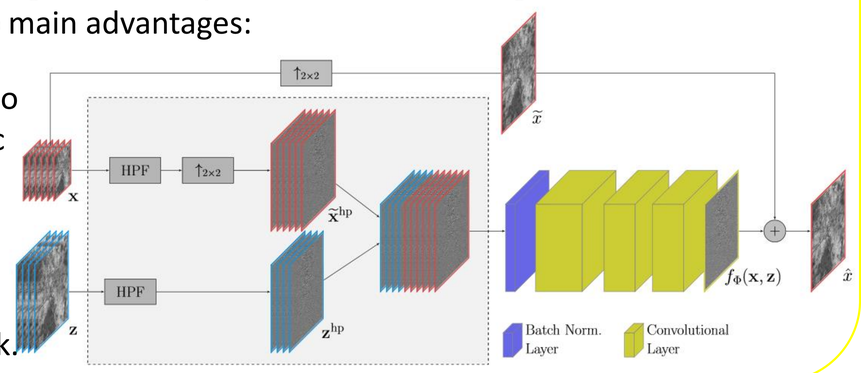
The 4 Layers Convolutional Neural Network is leveraged (CNNs) to provide a fast, upscalable method for the single-sensor fusion of Sentinel-2 (S2) data.




### Top-level workflow

The deterministic preprocessing bounded by the dashed box changes from one band to another, and presents two main advantages:

- computational advantages to super-resolve only a specific band;
- reaching the desired loss levels more quickly than using a single wider network.



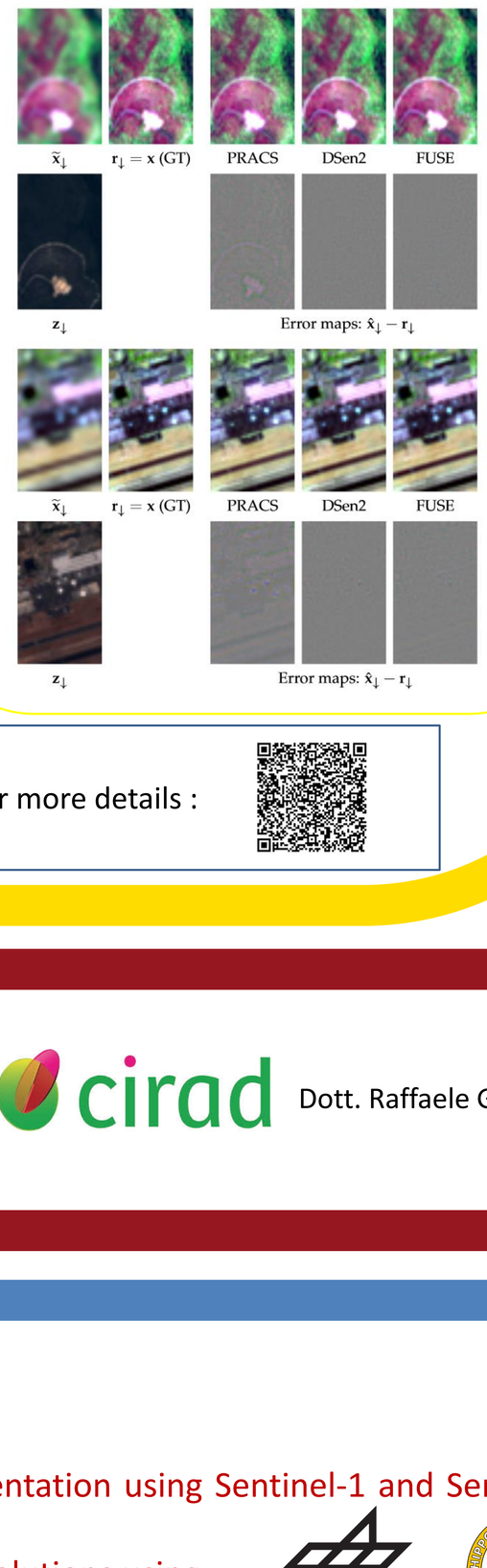

### Further Development: Multi-Loss

$$\mathcal{L} = \lambda_1 \mathcal{L}_{\text{Spec}} + \lambda_2 \mathcal{L}_{\text{Struct}} + \lambda_3 \mathcal{L}_{\text{Reg}} \qquad \lambda_1 = 1, \lambda_2 = 0.1, \text{and } \lambda_3 = 0.01$$

$$\begin{aligned} \mathcal{L}_{\text{Spec}} &= \mathrm{E}\left\{\left\|\hat{x}_{\downarrow} - r_{\downarrow}\right\|_1\right\} \\ &= \mathrm{E}\left\{\left\|f_{\Phi}(\mathbf{x}_{\downarrow}, \mathbf{z}_{\downarrow}) + \widetilde{x}_{\downarrow} - r_{\downarrow}\right\|_1\right\} \end{aligned} \qquad \mathcal{L}_{\text{Struct}} = \mathrm{E}\left\{\sum_{i=1}^{4} \left\|G_i(\hat{x} - r)\right\|_{1/2}\right\} \qquad \mathcal{L}_{\text{Reg}} = \mathrm{E}\left\{\left\|\nabla \hat{x}\right\|_1\right\} = \mathrm{E}\left\{\left\|\nabla f_{\Phi}(\mathbf{x}, \mathbf{z}) + \nabla \widetilde{x}\right\|_1\right\}$$

A combined loss that explicitly accounts for spectral (Spec) and structural (Struct) consistency is defined.

### Visual Inspection




### Numerical and Computational Time Comparisons

| Method (Ideal) | Reference-Based Q (1) | HCC (1) | ERGAS (0) | SAM (0) | No-Reference QNR (1) | $D_\lambda$ (0) | $D_S$ (0) |
|---|---|---|---|---|---|---|---|
| PRACS | 0.9767 | 0.7284 | 2.274 | **0.0019** | 0.8800 | **0.0847** | 0.0395 |
| DSen2 | 0.9916 | 0.8712 | 1.480 | 0.0194 | 0.8684 | 0.1028 | 0.0330 |
| FUSE (3 layers) | 0.9931 | 0.8602 | 1.631 | 0.0020 | 0.8521 | 0.1082 | 0.0474 |
| FUSE (L1 loss) | 0.9930 | 0.8660 | 1.681 | 0.1963 | 0.8570 | 0.1081 | 0.0410 |
| FUSE (full version) | **0.9934** | **0.8830** | **1.354** | 0.0184 | **0.8818** | 0.1002 | **0.0203** |

| | GPU Memory (Time) | | | | |
|---|---|---|---|---|---|
| Im. Size | 512 × 512 | 512 × 1024 | 1024 × 1024 | 1024 × 2048 | 2048 × 2048 |
| DSen2 | 6.6 GB (3.4 s) | 8.7 GB (4.3 s) | 9.2 GB (7.4 s) | 17.4 GB (9.8) | out of memory |
| FUSE | 391 MB (6×0.45 s) | 499 MB (6 × 0.47 s) | 707 MB (6 × 0.50 s) | 1.1 GB (6 × 0.55 s) | 1.9 GB (6 × 0.60 s) |

### Produced Papers


- M Gargiulo, A Mazza, R Gaetano, G Ruello, G Scarpa, **Fast Super-Resolution of 20 m Sentinel-2 Bands Using Convolutional Neural Networks** - Remote Sensing
- M Gargiulo, DAG Dell'Aglio, A Iodice, D Riccio, G Ruello, **A CNN-Based Super-Resolution Technique for Active Fire Detection on Sentinel-2 Data** - PIERS 2019
- M Gargiulo, **Advances on CNN-based super-resolution of Sentinel-2 images** - IGARSS 2019
- M Gargiulo, DAG Dell'Aglio, A Iodice, D Riccio, G Ruello, **Semantic Segmentation using Deep Learning: A case of study in Albufera Park, Valencia** - MetriAgriFor 2019
- DAG Dell'Aglio, M Gargiulo, A Iodice, D Riccio, G Ruello, **Active Fire Detection in Multispectral Super-Resolved Sentinel-2 Images by Means of Sam-Based Approach** - RTSI 2019


For more details :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### Future Developments of Super Resolution and Semantic Segmentation Approaches

- An Input Filter obtained with the usage of Convolutional Neural Network
- More Complex Architectures
- Investigation of other Losses
- Data Fusion for semantic segmentation using Sentinel-1 and Sentinel-2 information
- Investigation of Deep Learning Solutions using Unsupervised and Supervised learning