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GAMMALEARN: DEEP LEARNING APPLIED TO THE CHERENKOV TELESCOPE ARRAY (CTA)

Mikaël Jacquemont

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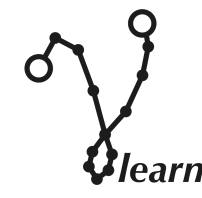
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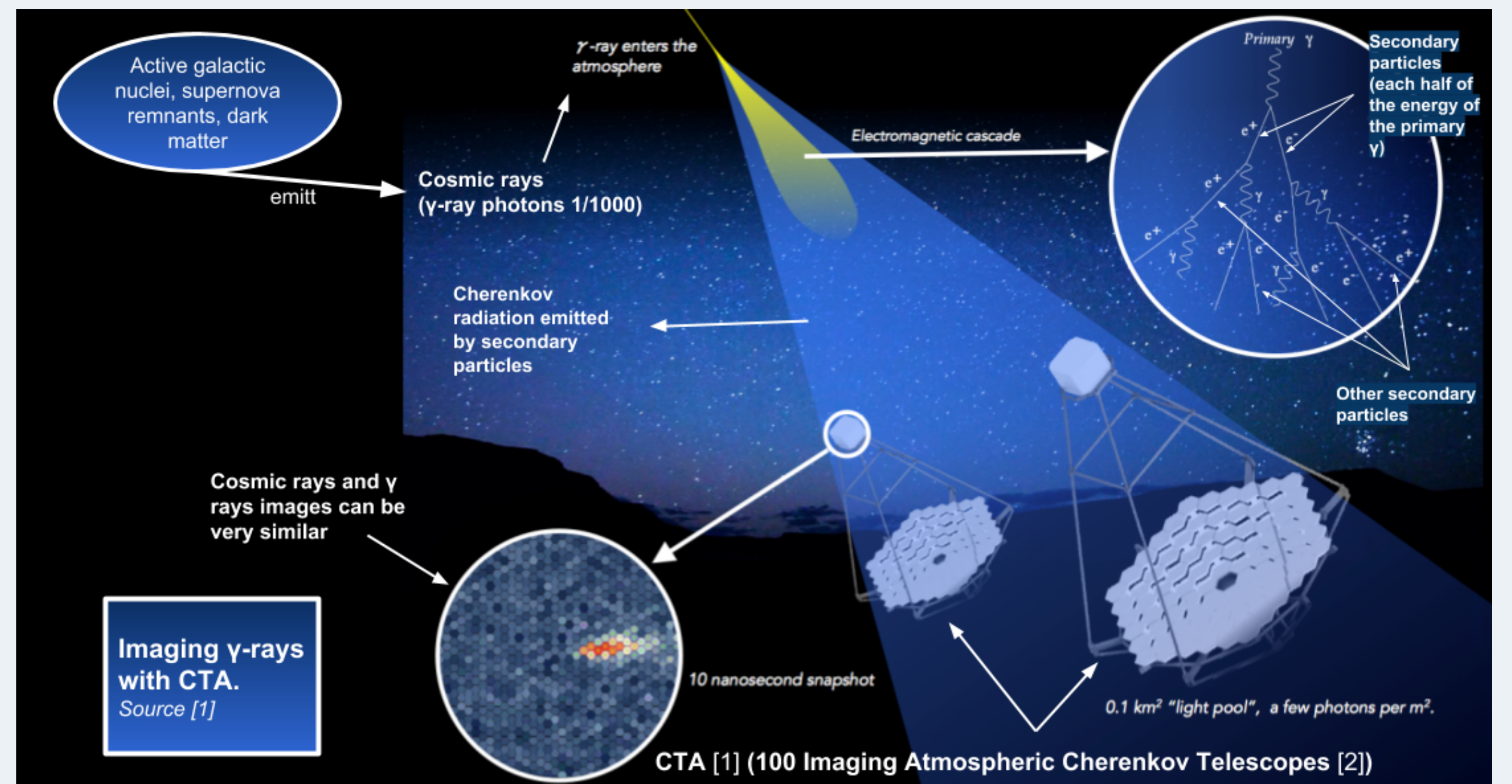
Jacquemont M. for the CTA Consortium
University Savoie Mont Blanc
mikaël.jacquemont@univ-smb.fr



Abstract

The Cherenkov Telescope Array (CTA) is the next generation ground-based observatory for γ -ray astronomy. It will be used to study γ -ray sources, allowing to better understand the Universe. It will generate petabytes of data per year, leading to big data challenges. The GammaLearn project proposes to apply Deep Learning as a part of the analysis of this huge amount of data. Its goal is to separate the γ photons from cosmic particles, and reconstruct the γ photons parameters, from noisy unconventional images (hexagonal grid, non rectangular shape).

Cherenkov Telescope Array



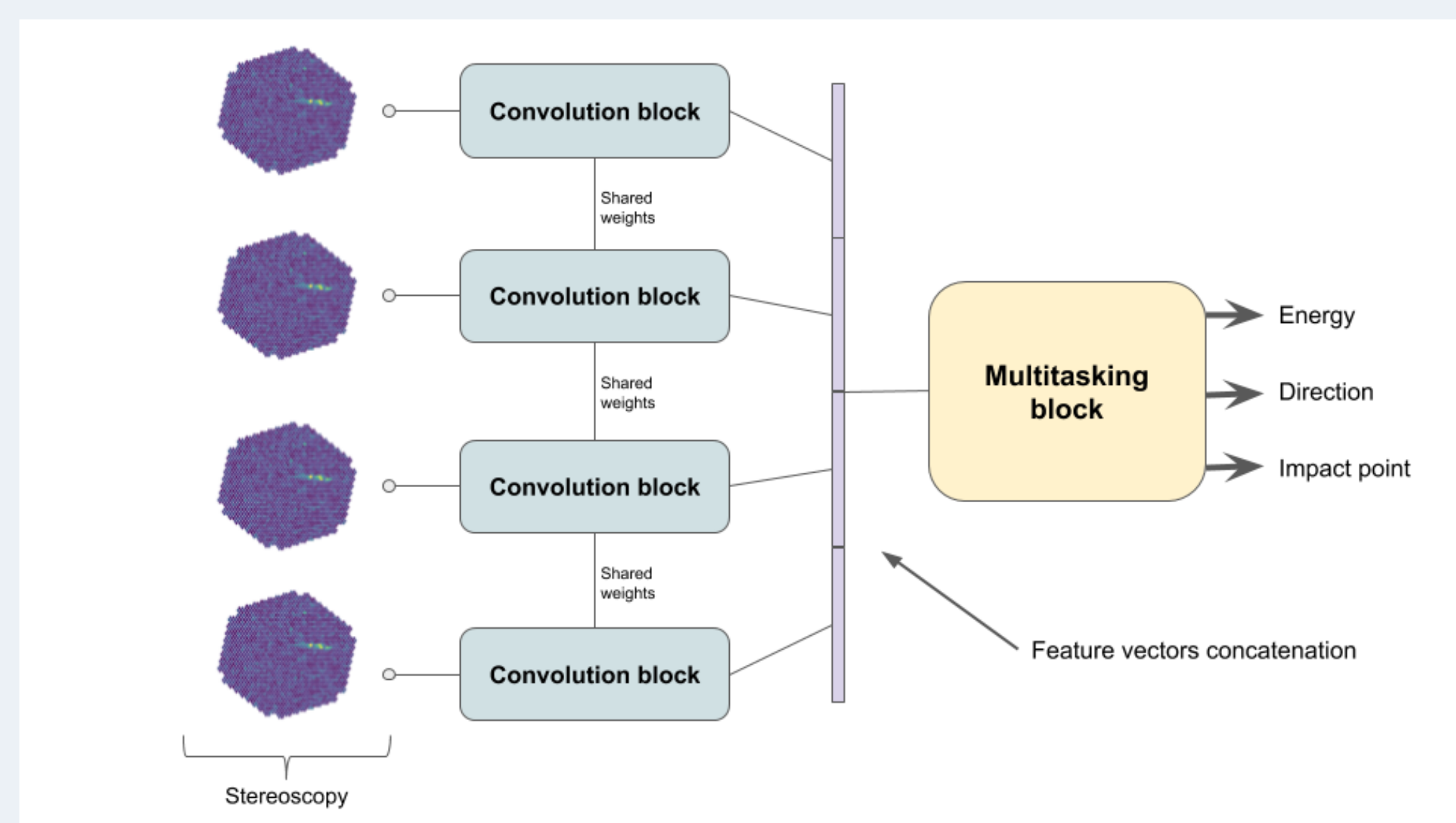
Deep Learning applied to CTA

Deep learning has already been applied to IACT data analysis [3][4], showing promising results. GammaLearn is a collaborative project involving the LAPP, the LISTIC and Orobix aiming to explore Deep Learning for CTA data analysis [5].

Preliminary work

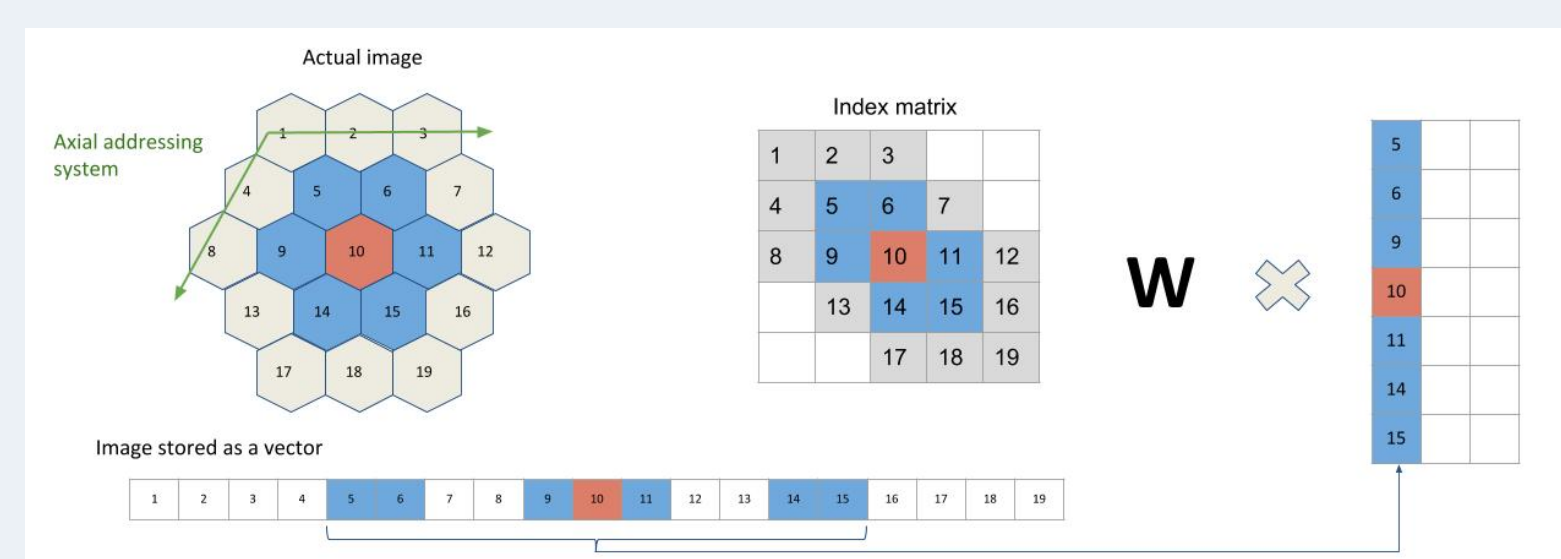
- **Regression** task (energy, direction and impact point) with an extended CNN (Supervised training).
- Raw simulated data : 90528 γ **diffuse** events, altitude 60° to 80° , azimuth -28° to 28° , energy 3GeV to 330TeV .
- Focusing on Large-Sized Telescopes (LST) among the telescope types of CTA (camera with hexagonal grid).

Architecture

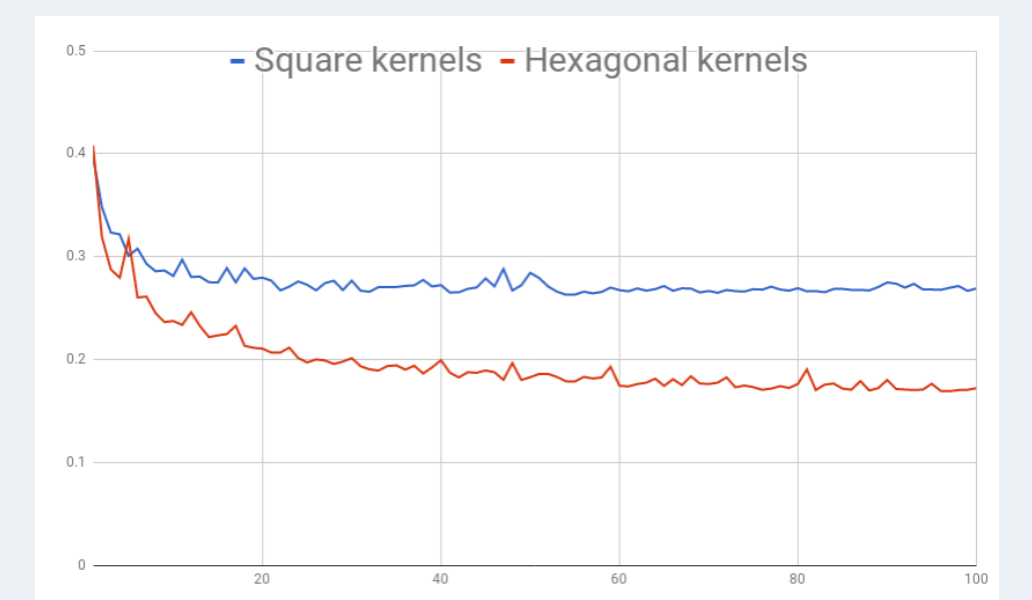


Stereoscopy analysis realized with a **multi-inputs multitasking** architecture using **hexagonal kernels** for convolution and pooling.

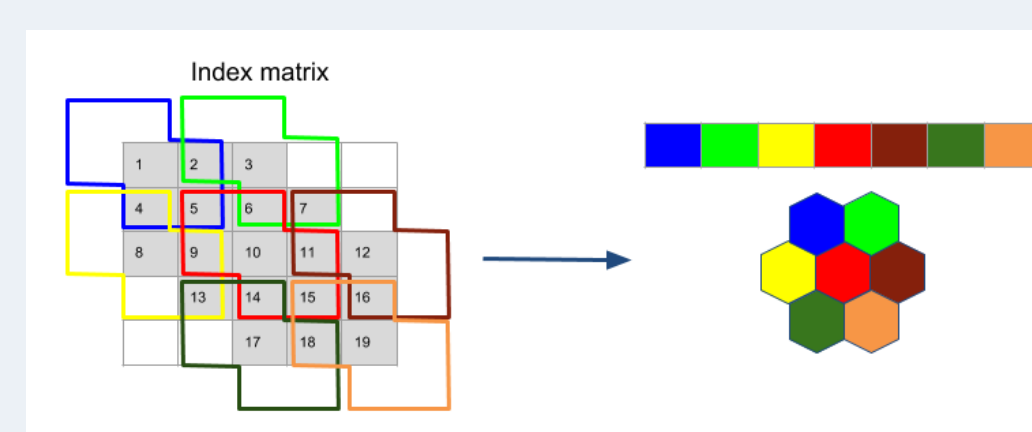
Hexagonal kernels



Hexagonal kernel via index matrix for convolution.



Global multitasking validation loss comparison.



Hexagonal kernel via index matrix for pooling.

On images with hexagonal grid, using **hexagonal kernels** (nearest neighbors) for convolution and pooling improves the global loss of the model by 19%.

Future work

- Improve the multitasking block according to physics and estimate aleatoric and epistemic uncertainties.
- Experiment more complex architectures.

References

- [1] <https://www.cta-observatory.org>
- [2] H. Völk, K. Bernlöhr, Imaging very high energy gamma-ray telescopes, in *Experimental Astronomy*, 2009
- [3] Shilon *et al.*, Application of Deep Learning methods to analysis of Imaging Atmospheric Cherenkov Telescopes data, in *arXiv preprint arXiv:1803.10698*, 2018
- [4] D. Nieto, A. Brill, B. Kim *et al.*, Exploring deep learning as an event classification method for the Cherenkov Telescope Array, in *35th International Cosmic Ray Conference - ICRC2017*, 2017
- [5] <https://lapp-gitlab.in2p3.fr/GammaLearn/GammaLearn>

Acknowledgments

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