

Istituto Nazionale di Fisica Nucleare Sezione di Padova

IACT Analysis using Convolutional Neural Networks

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Convolutional Neural Networks

- State of the art in computer vision
 - Used for self-driving cars, natural language processing, etc...
 - Use for IACTs:
 - Regression problems: Energy and Direction reconstruction
 - Classification problems: Gamma/hadron separation
- Being explored with significant improvements by currently working and future IACTs:
 - Shilon et al., "Application of Deep Learning methods to analysis of Imaging Atmospheric Cherenkov Telescopes data", APh (2018).
 - Parsons et al., "Background Rejection in Atmospheric Cherenkov Telescopes using Recurrent Convolutional Neural Networks", EPJC, (2019).
 - CTA dedicated working group working on optimization using Deep Learning.



Working with GPUs

- Scientific computing is moving from CPUs to GPUs
- Advantages/Disadvantages:
 - GPUs can perform simpler but more parallelized computations

- Setup for CTA @ Padova:
 - We started with two "borrowed" GPUs
 - Now:
 - NVIDIA Quadro RTX 6000 (5 k€)
 - NVIDIA Titan V (through NVIDIA Grant)



 In general, in one year the university has multiplied by 4 the number of GPUs hosted

IACT Analysis





1.0

0.5

-1.0

1.0

0.5

0.0

-0.5

15

35

30

25

20

Y position (m)

 $^{\circ}$ position (m)

PhD student at University of Leuven - Toyota





Dataset: MC gammas and hadrons

Input:

- charge information: one-channel input image.
- charge+time information:twochannel input image.



- Energy resolution improved up to a factor 2.6
- Angular resolution improved up to a factor 3.7
- Caveat: LST analysis using Random Forest not optimized
- Currently working with a new dataset and working on the paper for the LST single-telescope performance.



Intern at Dipartimento di Ingegneria della Informazione University of Padova

MAGIC real data analysis using CTA



- Dataset:
 - MC gammas and hadrons
 - Real MAGIC Data from Crab Nebula observations (2018 2019)

Performance on MC Energy resolution Angular resolution



9

Very fresh (from the oven), very preliminary results



Summary

- CNN analysis is the next and natural step in the analysis of IACT data.
- Already attacking the problem from several fronts
 - LST MC simulation analysis improved by a large amount using CNNs
 - MAGIC simulation analysis also improved, currently working on real data and reaching state-of-the-art sensitivities
- Material
 - N. Marinello master thesis: <u>https://userswww.pd.infn.it/~rlopez/</u> <u>Theses/Directed/Thesis_Nicola.pdf</u>
 - E. Mariotti master thesis: <u>https://userswww.pd.infn.it/~rlopez/</u> <u>Theses/Directed/2019_04_Ettore.pdf</u>

The real hard workers behind this

