The Second CTA Pipeline Developer's Workshop

Advanced Image Cleaning

Jérémie Decock

CEA Saclay - Irfu/SAp

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Introduction

Subject

Try to improve image cleaning before *Hilas parametrization*

Improve methods to remove:

- Instrumental noise
- Background noise

Motivations:

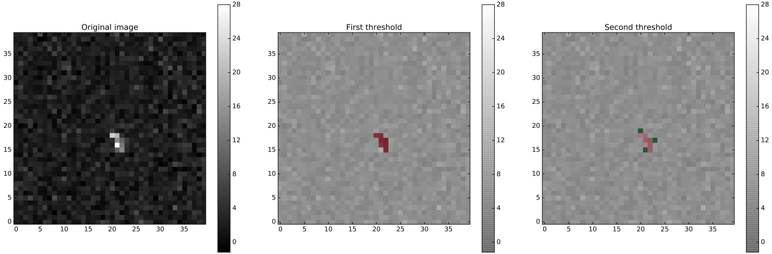
- Keep more signal (deeper into the noise)
- Reduce threshold
- Maybe eventually do cleaning and time-integration all at once

Current method (HESS)

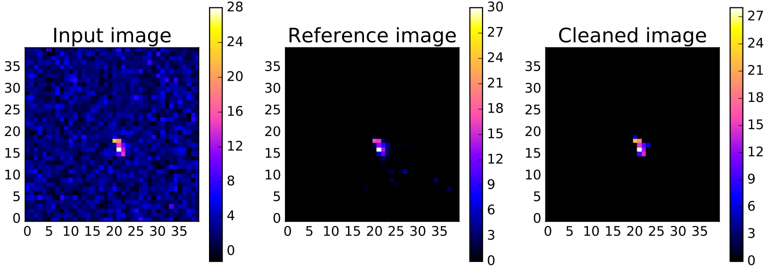
The "Tailcuts clean" algorithm

A very simple cleaning procedure:

- Keep pixels above a given threshold (e.g. 10 PE)
- Keep some neighbors of these selected pixels: those above a second (lower) threshold (e.g. 5 PE)



Example


Input image
Reference image
Cleaned image
0 5 10 15 20 25 30 35
28 24 20 16 12 8 4 0
30 27 24 21 18 15 12 9 6 3 0
27 24 21 18 15 12 9 6 3 0

Remarks

- Fast and simple
- Sufficient for bright showers
- But surely we can do better for faint showers

An alternative method

Basic idea

- Tailcut method: threshold in the main space
- Better idea: threshold in a different space where signal and noise can be easily separated

Wavelet Transform method

Roughly the same idea than doing filtering with Fourier Transform

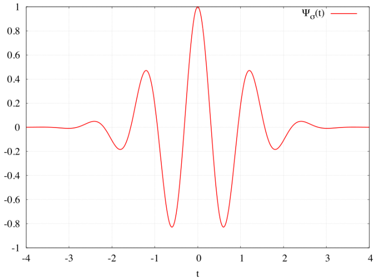
- Apply the transform on the signal
- Apply a threshold in the transformed space
- Invert the transform to go back to the original signal space

Differences with Fourier Transform

- Use *wavelets* instead sin and cos functions as new bases in the transformed space
- The transformed space contains spatial information

Overview

A wavelet looks like this (Morlet):



"A wave-like oscillation with an amplitude that begins at zero, increases, and then decreases back to zero"

Conclusion

Conclusion

This is a work is in progress... We will try to give some first results in Bologna Meeting or soon after

Thanks to CosmoStat we have some tools to apply wavelet transforms ("mr_transform")

References I

Appendix

Clarifications

Different kind of "noise" in telescope images (*to be completed...*)

1. Instrumental noise (Photomultiplier Tubes, ...)
    - Thermionic emission
    - Radiations
    - Electric noise
2. Background noise (*Night Sky Background* or NSB)
    - Parasite light (moon, stars, planes, light pollution, ...)

The "Tailcuts clean" listing (Python)

```python
def tailcuts_clean(geom, image, pedvars,
    picture_thresh=4.25, boundary_thresh=2.25):

    clean_mask = image >= picture_thresh * pedvars
    boundary_mask = image >= boundary_thresh * pedvars

    boundary_ids = []
    for pix_id in geom.pix_id[boundary_mask]:
        if clean_mask[geom.neighbors[pix_id]].any():
            boundary_ids.append(pix_id)

    clean_mask[boundary_ids] = True

    return clean_mask
```

listings/tailcuts_clean.py

First alternative

Discrete Fourier Transform method

- Previous filter: threshold in the main space
- Better idea: threshold in a different space where signal and noise can be easily separated

Fourier transform

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos(nt) + b_n \sin(nt))$$

$$a_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(t) \cos(nt) dt$$

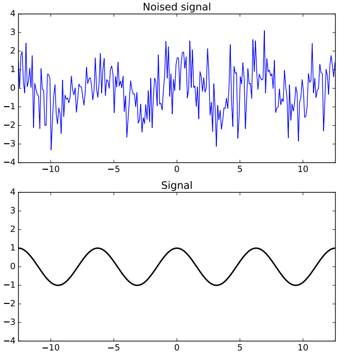
$$b_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(t) \sin(nt) dt$$

Discrete Fourier Transform (DFT)

Fourier Transform for discrete signals (digital pictures, ...)

Clean signals with DFT

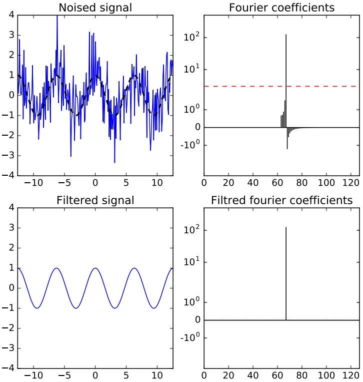
Remove noise in direct space: difficult (here)



Clean signals with DFT

Remove noise in transformed space: easy (here)

- Apply DFT
- Apply a threshold
- Apply invert DFT



Remarks

FFT can be applied to any T-periodic function f verifying the *Dirichlet conditions*:

- f must be continuous
- *and* monotonic
- on a finite number of sub-intervals (of T)

Signals defined on bounded intervals (e.g. images) can be considered as periodic functions (applying infinite repetitions)

Analyse

Works well:

- when the Fourier coefficients for the signal and the noise can easily be separated in the Fourier space (obviously...)
- e.g. when either the signal *or* the noise can be defined with few big Fourier coefficients (i.e. signal or noise have a few number of significant harmonics)