Flare detection from discrete Fourier transforms of SJIs

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Overview

- We present a new method to detect solar flares based on the IRIS slit-jaw images (SJIs). Usually the detection is made based on intensity cutoffs, but this can easily result in the detection of small energetic events without any actual flare appearing.
- Our method reduces the false detections of flares by taking into consideration their specific pattern. For now, we have a **99% detection accuracy on 500 sequences of 10 consecutive frames for 1400Å SJI frames, with one sequence missed and no sequence with false detection**.
- The high accuracy in automatic flare detection firstly contributes to **the creation of a large labeled IRIS dataset of flares**, a condition for analyzing them with more machine learning technics.
  We also present **useful tools** which could help anyone for the preprocessing and analysis of IRIS SJIs.

Method & Tools

We assume that the **temporal component is important** for detecting flares, sometimes even for experienced observers. To this end, we developed a tool to **extract the time variations of the frequencies** observed in SJI videos.
Among the many different frequency patterns, we empirically picked parameters appearing to correspond to flaring profiles and derived an output probability for flare occurrence.
The frequency patterns are obtained **locally** from small video patches, whereas the output probability is **global** on the full frame size.
Before applying this analysis, the raw SJIs are preprocessed by **recovering with good quality the missing data**. This step turned out to be crucial for better results.

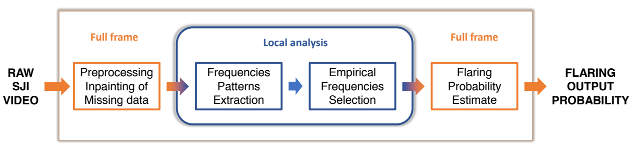

Fig.1 Our pipeline for automatic detection of flares

Frequency extraction

*We are using **discrete cosine transforms (DCT)** which are similar to discrete Fourier transforms (DFT): It transforms a signal (1D case) or an image (2D case) **from the spatial domain to the frequency domain** (Fig.2).*
*It uses the **basis of cosines** instead of complex exponentials, which is **invertible,** computationally cheaper than DFT and well suited for real signals such as videos.*

Local analysis (A) computed for all the patches of the full SJI video *(Fig.4)*.
Input: Small video patch of size 20 x 20 x 10 (height x large x time)

Apply *2D DCT* for each frames
Prevents possible misalignment of spatial coordinates over time

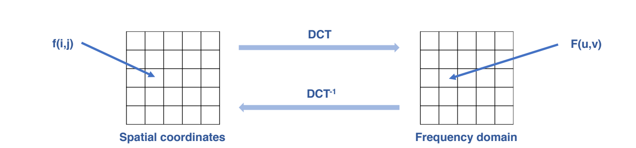

Fig.2 Illustration of 2D DCT

Apply *1D DCT* for each spatial frequencies coordinates
Extracts the frequencies of the temporal signal for each coordinates
Get the variances of those temporal frequencies

Output: Temporal variances of the spatial frequencies observed in the video patch

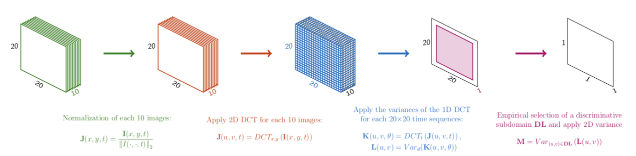

Fig.3 Chain of SJI video patches processing for frequency patterns extraction

Frequency selection

Local analysis (B)
For each SJI filters, we **empirically** select a subdomain of spatial frequencies for which the patterns seem to give different results for flaring cases.
The local analysis results in the spatial variance over the selected subdomain.
This is not optimal and fully handcrafted but good enough to detect flares.

Flare probability

Full frame analysis (C)
For each SJI filters, we derive from the variances of all the local analysis results an estimation of the full frame probability for a flare.
We tuned the parameters of the probability function in order to get results between 0 for no flare and 1 for flare.

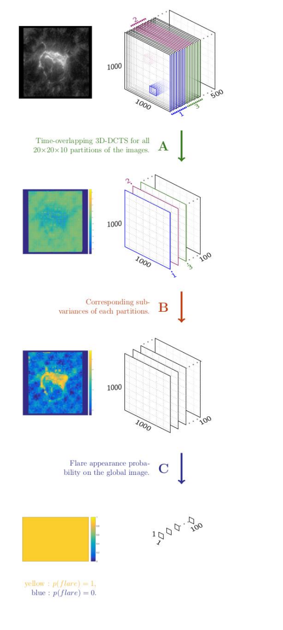

Fig.4 Representation of the detection on SJI videos
In this case, a flare is detected: yellow output means that the probability of flare is 1

Results

detection	true flare	true no-flare
flare	43	0
no-flare	1	456

On 500 videos of 10 frames of 1400Å SJIs

Recovering missing data

Recovering the missing data (e.g., dust) with good quality turned out to be crucial for better flare detection results. We propose a new tool for this, giving **smoother** and **more realistic** inpainting than similar IRIS tools of our knowledge.

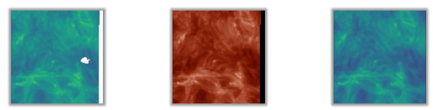

Fig.5 a. Raw data, b. Classic dust remover, c. Our preprocessing

The preprocessing shows **high performance** for any small area of missing data, and also for large areas if there is information nearby in time at the given location.
The missing data is recovered by all the information contained in the SJI video data-cube, being firstly initialized to the values of the 3D nearest neighbors and then by recursive smoothing.
This tool is very widely inspired by two articles:

Garcia D. Robust smoothing of gridded data in one and higher dimensions with missing values. Comput Statist Data Anal, 2010;54:1167-1178
Wang G, Garcia D et al. A three- dimensional gap filling method for large geophysical datasets: Application to global satellite soil moisture observations. Environ Modell Softw, 2012;30:139-142

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www.nrp75.ch

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The python library of these methods will be soon available online.
New features are also planed. Please contact me.

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We present a new method to detect solar flares based on the IRIS SJI. Usually the detection is made based on intensity cutoffs, but this can easily result in the detection of small energetic events without any actual flare appearing. Our method reduces the false detections of flares by taking in consideration the specific pattern of flares.

By using sequences of 10 consecutive SJIs, we place importance on the temporal component of flares. These short videos are parcelled in small blocks of size 20×20 pixels to analyse the local variations of the frequencies by looking at the variance of the discrete Fourier transform (DCT) of the signal. Each frame is also pre-passed through the 2-dimensional DCT in order to be well aligned. We then found parameters to distinguish the flare sequences from the non-flare sequences.

For now we have a 99% detection accuracy on 500 sequences of 10 consecutive frames for 1400A SJI, with 1 sequence missed and no sequence with false detection.

To conclude, we would like to present results of our method in a E-Poster to show videos of results. We use some handcrafted supervised machine learning techniques to show that it is possible to accurately detect flares from the SJI with this method. Firstly, it will allow us to create a complete automatic list of flares in the IRIS database. Secondly, our tool will also help us analyzing the flares with more machine learning techniques. Our work is supported by the Swiss National Science Fondation (SNF) National Research Program 75 "Big Data" and we want to acknowledge LMSAL for the access to the IRIS database.