Filtering Algorithm for MODIS Time Series Data

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Abstract. *This paper describes an easy to use and friendly Graphical User Interface (GUI) of a smoothing tool for remote sensing time series, focused in MODIS data. This tool is developed in Python environment and thus uses packages, libraries, modules and functions to retrieve and filter time series data, and display temporal information based on user defined parameters. The GUI allows users to choose MODIS products, different noise-removal filters, parameters for outlier removal, and also creating animations based on the time series, of predefined areas. Time series processed by our system can be downloaded in the well known CSV format, to be used in other applications.*

1. Introduction

Many imagery, along the detection procedure, are often affected by what they were not expected to be. We can consider that everything that sensitize the detectors, which were non expected, may be concluded as noise. Literature considers this in a negative way, claiming that it is something to be removed from images [Lisi et al. 2015, Xu et al. 2019], unless the goal of research is exactly the evaluation of the atmosphere interference. Noise is measured in relation to the signal that achieves the detectors. Signal is the information acquired from the surface that, in fact, matters to remote sensing. The relation between them is so interpreted such as signal-to-noise (S/N) ratio [Siegle and Trapp 2016]. The S/N is defined as if it was the ratio between the variance of the signal and the variance of the noise, in a way that the higher the signal, the higher the quality of the image [Yan et al. 2016].

Taking into account the above context, procedures are necessary to be implemented as a form of solving the problem commented. In this paper we used an algorithm which identifies and removes the noise from the Moderate-Resolution Imaging Spectroradiometer (MODIS) imagery time series. Our goal was to create a friendly graphic platform that allows the user to choose a filter for smoothing data and work with the information with less noise. This link [1] provides a video with more information.

2. Contents of the Platform

The following packages and libraries were used: gi (Gtk and GObject, version 3.0), sys, wtss, datetime, csv, scipy, math, os, functools, shapely, time, matplotlib, multiprocessing, numpy and pyshp (shapefile). For proper functioning of the platform it is required an internet connection, once all the packages and libraries are brought up from the web.

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[1]https://drive.google.com/open?id=1KHKe4PqqaDM5u4vaEuDWc83bpnADtJbQ

Wtss is a web service based on MODIS products [de Queiroz et al. 2015], which imports the time series profile to the platform. Filtering algorithm here presented makes use of MOD13Q1 product, which brings the blue, red, near and middle infrared bands, plus the NDVI and EVI vegetation indexes, and also MOD13Q1-M product, which presents quality and reliability bands. Users are able to select the band, index and the time series period they are willing to analyze. The analysis is based on the pixel, requiring the input of Lat/Long coordinates. Moreover, the user can also import a shapefile to the platform and view the time series change in an area through a Graphics Interchange Format (GIF).

For now there are five filters implemented, which are: Pyramid Filter, Mean Filter, Gauss Filter, Savitzky-Golay Filter and Whittaker-Eilers Filter. Selecting the chosen one, the parameters of the filter can be set, such as size, standard deviation, polynomial order, graph type (line or polar). Besides, an outlier removal tool is available. It is also possible to export the filtered data in ".csv" format or the graph in some image formats. Figure 1, shows an example of a line graph with raw, outliers removed, and smoothed data. It reveals the disaster occurred in Mariana (MG, Brazil) in November of 2015, where a tailings dam disruption caused a significant inundation and destruction of the region. This impacted the NDVI, as shown by their low values for 2016.
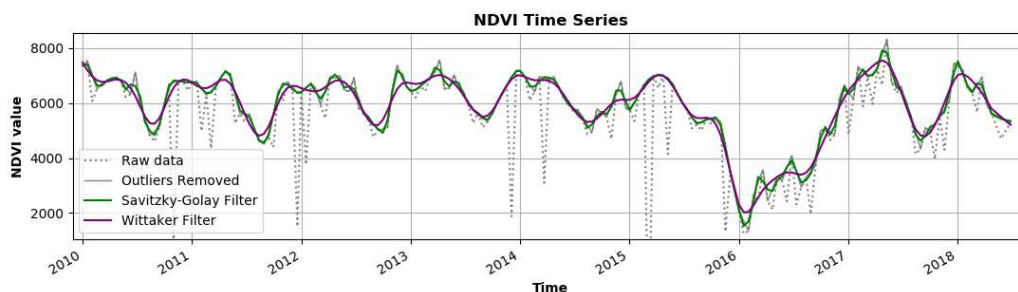
Figure 1. Line graph profile showing both the raw and smoothed data.

The tool can also create an animation for the time series within a polygon, inserted via a shapefile. All the time series located inside this polygon is acquired, and the animation is constructed based on the time stamps of the time series, where each date is used as a single frame. This animation can be used to understand the behaviour of the series according to its neighbours.

3. Main Filters

In this tool, 4 main filters could be implemented: a Mean Filter, a Gauss Filter, a Savitzky-Golay Filter, and a Whittaker-Eilers Filter.

The mean filter is of a linear class, which smooths signal. It works as a low-pass filter, which in images can cause a blur effect. The filtered pixel will be the product of the average taken across its neighborhood.

The gauss filter uses a Gaussian function to extract weights which will be applied to the value of the time series' pixels according to their position on the window. The products' sum is divided by the sum of all weights. The parameters to this filter are the window size and the standard deviation of the Gaussian function.

According to [Press et al. 1986], a simple generalization of the Savitzky-Golay filter would be to do a least-squares fit within a moving window around each data point, one containing a fixed number of data points to the left and right. The input parameters are the window size, the polynomial adjust order, the derivative's order and the tax. This filter was implemented according to the following literature [Savitzky and Golay 1964].

The Whittaker-Eilers filter [Eilers 2003] is based on a model that assumes an unknown piecewise polynomial smooth curve and puts a penalty on the integral of the squared second derivative. According to [Chountasis et al. 2012], it can be easily adapted to fit data with missing values and data that are arbitrarily non equally spaced.

4. Conclusions and Further Approaches

The implementation of the filtering algorithms fits to the objective initially raised. It is able to remove from the raw data, the inconsistent information, letting the data smoothed and thus free from noise, obtaining, finally, a signal-to-noise ratio that is suitable for analyses. Despite the proper functionality of the algorithm, it still may be boost in order to let the platform much more usable for a larger community. Improvements such as increasing the type of coordinates that can be insert, choosing the location of the analyses directly over a map, amplifying the amount of graph types and introducing products of other satellite families, are all further approaches to be chased in order to improve the functionality and the achievement of this algorithm in new versions.

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