Computer Vision based Seismic Detection

Seismic Detection Across the Solar System

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Introduction

Within the framework of the "NASA Space Apps Challenge," a solution is proposed to the problem presented by the challenge "Seismic Detection Across the Solar System" through the project called “Computer Vision based Seismic Detection” which is based on identifying abrupt signals through an image detection program.

Problem

Both Mars and the Moon record daily seismic signals that are sent to Earth for geodesic studies of these heavenly bodies. Each signal transmission incurs a high energy cost, presenting a challenge and expense that can be reduced. The challenge proposes to detect within each daily recording the signals that are clearly seismic events or abrupt changes among the rest of the signal.

This problem is important for both the scientific and commercial communities because:

- It provides a lower energy cost for seismic stations, a crucial factor in missions that rely on efficiency.
- The reduction of 93.10% of data sent to Earth contributes to a more sustainable approach to space exploration. By minimizing resource use in communication infrastructure, we are taking a step toward a more responsible and eco-friendly future.
- It decreases redundancy. By filtering and sending only relevant data, we avoid information duplication. This improves the efficiency of data storage and processing on Earth, allowing scientists to focus on what truly matters.
- It reduces stress on communication systems. This not only enhances the quality of transmissions but also increases the reliability of the information we receive.

Computer-Vision-Based-Seismic-Detection

This program aims to detect abrupt changes from a gray-scaled image of a spectogram graph of a signal, take the data and transform it again to arrival and end time of the seismic signal.

Images to detect changes in signals

Image detection program for signals is a unique, creative and advantageous approach due to its practicality, interactivity, and exponential areas of application. Also, the program is scalable for exporting images that can be applied in various contexts.

Visualizing the signal is a distinct way of tackling this problem, making it interpretable and understandable for both experts and people who do not have technical knowledge; this allows it to be a usable and customizable program for a broad audience.

Advantages of image detection

- Visualization.
- Understanding.
- Scalability.
- Easy way to fit the model.

Error traceability: by visualizing the images with the detected bounding box, you can focus the attention on the most interesting part of the graphic.

Another advantage of the program is that it can be adjusted for the detection of multiple earthquakes within a single signal.

¿How does it work?

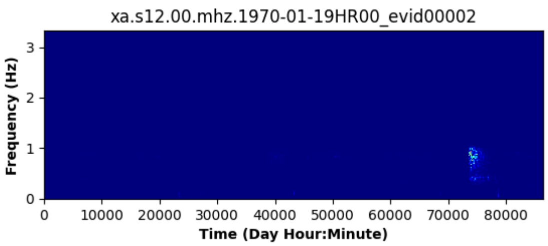
The program has got 6 functions:

1. **Signal Reading**: The signal is read in .mseed format, to extract traces and time in seconds.
2. **Plotting the Signal Graph**: The signal graph is plotted, and an image of the graph is saved in black and white.
3. **Second-to-Pixel Ratio**: The ratio of seconds per pixel in the image is calculated. That is, how many seconds each pixel in the image represents.
4. **Image Color Adjustment**: An adjustment is made to the image scale so that the minimum value of the image corresponds to the minimum and the maximum value in the graphic.
5. **Detection**: Abrupt changes in the image are detected. First, Gaussian Blur is applied, then Canny, and finally, findContours. With the detected contours, the one with the smallest x-axis value and the one with the largest x-axis value are selected.
6. **Converting Pixel Value to Seconds**: Using the second-to-pixel ratio obtained earlier, the smallest x-axis and largest x-axis values found earlier are converted to seconds, becoming the values for the arrival and end times of the earthquake, respectively.

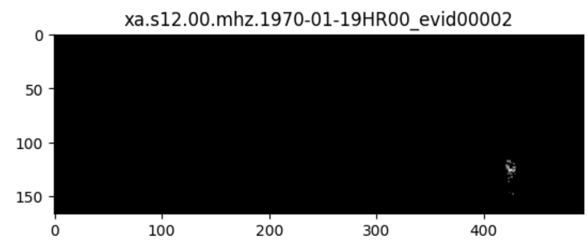
Funciones for each step:

Step	**Function**	**Details**
Signal Reading	get(tr)	This function obtains a variable 'st' from a .mseed file. Then it retrieves the traces from that file. It filters 'st' according to a minimum and maximum frequency, retrieves the traces from the filtered file, and returns them
Plotting the Signal Graph	def imagen(tr_filt)	This function creates a 2D plot: x: relative time y: frequency in Hz Then it saves the plot as an image. It loads the image into a variable. It crops the square of information from the image. It returns the image in np.array format.
Second-to-Pixel Ratio	sec_x_pix(img, tr_filt)	This function calculates the seconds-per-pixel ratio from a given image and a filtered trace.
Image Color Adjustment	imadjust(image, vin=None, vout=[0,255], gamma=1)	
Detection	detect(image,type_mq, sh = None)	This function detects the areas of the image where seismic frequency stands out. It does this by detecting changes in the image based on seismic parameters. It finds the contours and draws rectangles around the detected areas. It returns the minimum and maximum x-axis values among all the contours. If sh = True, it plots the image with the detected rectangle(s).
Converting Pixel Value to Seconds	arrival_end(x_min, x_max, sxp)	This function converts the x_min and x_max values to relative time (seconds) based on a seconds-per-pixel ratio.

Graphic explanation:



Spectrogram of the signal in a graph



Graph of the signal's spectrogram as a grayscale image.
Note how the axis scale shifts to pixels since it is now an image.

Signal detected with a bounding box

Requirements

Apart from Python, these libraries are required:

```
import matplotlib.pyplot as plt
from scipy import signal
from matplotlib import cm
import cv2
from obspy import read
import numpy as np
import pandas as pd
import random as rng
import seaborn as sns
```

Potential uses

This program can be used to analyze signals from various sources (not just seismic) since different parameters can be adjusted: kernel, threshold, minimum detected rectangle area. It can also be easily modified to use other detection methods besides Canny. Some potential fields of application are:

- Pathology Detection: Throughout the development, no cases of image detection in signal spectrograms for pathology detection in the medical field have been found (although image detection in ultrasounds or X-rays is known, not in signal analysis). In this sense, the project holds potential for detecting cardiological, SG, and EEG pathologies, as well as electroencephalographic detecting possible neurological disorders.
- Educational Field: Presentation and visualization of signals for explanatory use and learning in different areas.
- Predictive Maintenance: Analyzing noise in electrical systems to identify patterns suggesting imminent equipment failures, allowing for proactive maintenance. Finally, it can also optimize telecommunications networks by applying noise detection techniques to identify interference and improve transmission quality.

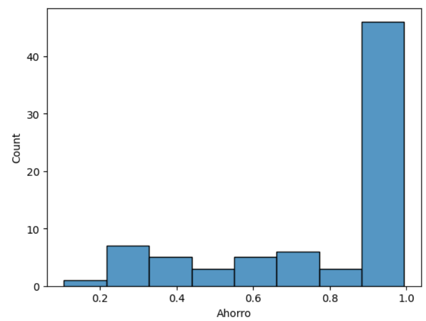
Metrics

This program stands out not only for solving the presented problem but also for offering significant data savings as support.

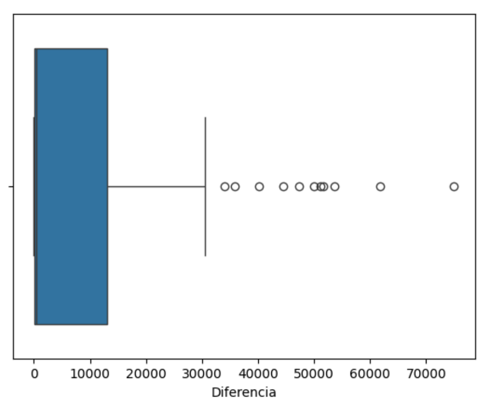
The program achieves a median data savings of 97.36%. That is, from an average of 84,000 seconds in a one-day recording, only approximately 2.64% is sent, which equates to around 2.217,6 seconds.

Below are some graphs that illustrate the program's performance:

A. Histogram of the savings for the train data.

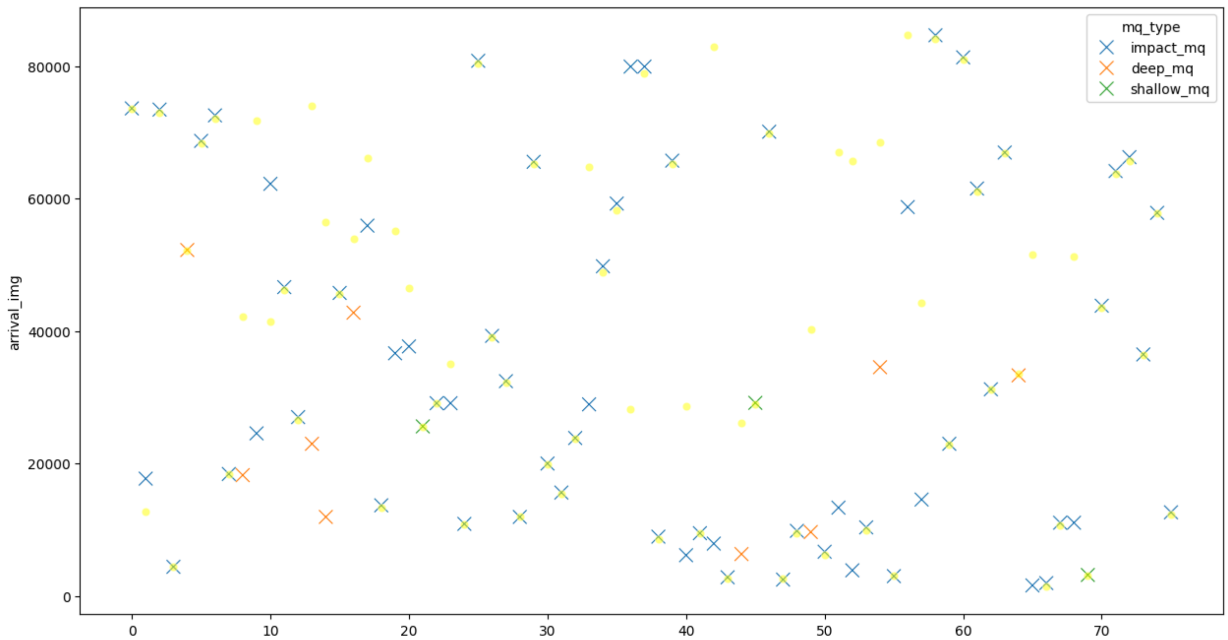


B. BoxPlot of the difference in earthquake start identifications from the image, compared with the start identifications provided in the dataset.



Only 0.14 of the data have a very large difference in their detection.

C. Histogram of the difference in earthquake onset identifications in the image, compared to the earthquake onset identifications provided in the dataset (in yellow, those identified by the program; the crosses are those identified through the program) it's divided by type of moonquake



Conclusions

A program is presented that not only offers an innovative and creative approach to anomaly detection in signals but also comes with metrics more than sufficient to support it. Another plus is that, speaking of detection errors in earthquake arrivals, it is important to note that in most cases this does not result in a loss of seismic signal but rather in a larger signal transmission window, within which the seismic signal is still present.

This program, in addition to improving the efficiency of planetary seismology missions, also opens up a range of possibilities in various fields.

The potential of this program is vast, and the impact it will have on the fields in which it is applied is invaluable.

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