A distributed processing and cloud based tool to deal with satellite image processing for shoreline analysis

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ABSTRACT

The analysis of shorelines is an important activity that can support specialist from several areas in decision making based on statistical analysis about evaluation of water segments over shorelines and the forecasting of its progress. However, to perform such analysis based on digital images it is necessary a huge data processing. Currently an extensive data set of images are available, that can be used as a source for shoreline analysis and can be processed by computers through image processing algorithms. In this context, this paper presents a technical perspective of a tool for performing shoreline analysis based on satellites images named Coastal Analyst System from Space Imagery Engine (CASSIE). This tool works as an orchestrator of cloud-based APIs. This paper presents the overall architecture of this tool as well as its main use cases. The evaluation of this tool is discussed based on its usage by specialists and the provided feedback.

KEYWORDS

Image processing, cloud computing, Google Maps API, Google Earth Engine, shoreline analysis.

1 Introduction

The climatic changes have been appointed as one of main causes for the sea level rise in many regions of the planet and as a consequence, many ecosystems and economy activities are impacted [1]. Such impact can be noticed by sea water advancing over lakes, mangroves and also by accelerated erosion of costs [2]. Hence, the understanding of most impacted areas is an important result for governmental activities and environment protection studies aiming to think about public politics or better investments to be performed in such areas. To support in such studies, tools that assist in the historical changes of shorelines and support its forecasting analysis can be helpful for a data driven decisions [3]. In this context, some studies [4, 5, 6] have already presented approaches to perform shoreline analysis though satellite imagery by software. However, aiming to provide a simpler way to use such techniques, this paper presents a tool named CASSIE which supports the shoreline algorithms execution by users from a web interface, that do not demand knowledge about programming or statistical software, hence can be utilized by professionals from many areas of interest. In this paper, we present the main background concepts in section 2, the related studies in section 3, the overview about CASSIE use cases and architecture in section 4 and its evaluation on section 5.

2 Background

In this section we present the concepts of shoreline analysis and the available satellite imagery collections that are the basis data source for CASSIE software.

2.1 Satellite derived shorelines and analysis

Mapping the shoreline position on multi-spectral satellite imagery consists histogram segmentation procedure that separates water from land on a given coastal area of interest [7]. Mapping and analyzing shoreline evolution through a historical time-series of digital images, requires an exhaustive and multi-task processing that involves selection and download of satellite imagery, image pre-processing (e.g. removing images with cloud presence, clipping images to corresponding to the area of interest, etc.), manual or automatic shoreline digitalization and statistical analysis [7]. As results from this analysis, it is produced transactors and its statistics which may indicate if the shoreline in a respective area of interest is stable, accreted, erode or even critically eroded [8].

2.2 Data sources: Landsat and Sentinel missions

The capture of images through the Satellites is a practice that has been performed along the years. Through this technology it is possible to perform the surface analysis from almost all globe, being possible to apply analysis methods over many different areas of interest. Moreover, the availability of historical imagery in a constant revisiting period can be very useful once it is possible to evaluate changes based on the advance of the time.

The National Aeronautics and Space Administration (NASA) maintains a mission named Landsat (https://landsat.gsfc.nasa.gov/) which provides images captures from the whole world since 1984, presenting spatial resolution of 30 meters. Each 16 days this satellite revisits each region. The European Space Agency (ESA) maintains a mission named Sentinel (**https://sentinels.copernicus.eu/**) which provides images captures from whole world surface since 2013 and with spatial resolution of 10 meters. It revisits each region every 5 days. Besides the historical content from Sentinel is reduced when comparing with Landsat, its frequency of image capture and spatial resolution are positive aspects for its usage. The access of both data sources is important to proper processing, once the quality of images is an important feature for the input quality of image processing algorithms. And often there are images that have a high presence of clouds, which can affect the processing, generating undesired results.

3 Relates studies

There are a few studies that have already presented results about software tools to provide shoreline analysis. A study that assists the shoreline analysis based on images from Landsat and Sentinel was already presented by [4]. This study has presented the accuracy of shoreline analysis based on Satellite based imagery. Another computer aim method for shoreline analysis was presented by [5] through the usage of AMBUR (Analyzing Moving Boundaries Using R). Also, another related work [6] presented a Python toolkit to assist in shoreline analysis based on Sentinel and Landsat imageries. Besides, this study also presents a valuable software for evaluating shoreline change, it is still restricted to a desktop environment, demanding a more technical dependencies for performing such analysis. Hence, this study aims to present a tool which process shoreline analysis based on cloud based and distribute processing APIs, with can be managed by a simple web interface that can be accessed from common web browsers with internet access.

4 CASSIE

CASSIE (https://cassiengine.org) was developed to be a user-friendly tool which can be accessed through web browsers. Besides, and the users can input all parameters and consume the output results directly in a web interface, without demanding to download or configuring additional software.

4.1. CASSIE main uses cases

The uses cases to perform through CASSIE are presented by an Unified Modelling Language (UML) use case diagram (Figure 1).

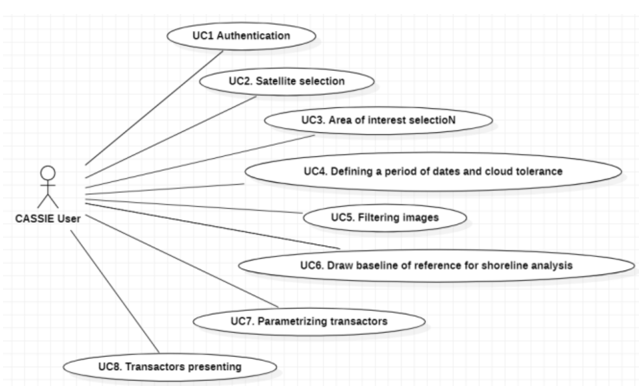

Figure 1: CASSIE use cases diagram

4.1.1. Authentication

The authentication use case demands an integration with Google authentication service. Then, more than have a google user account, the CASSIE user must have their google account enabled to use Google Earth Engine. On CASSIE main page, we have set all instructions for user authentication (Figure 2). It is not possible to utilize the tool without being logged on it.

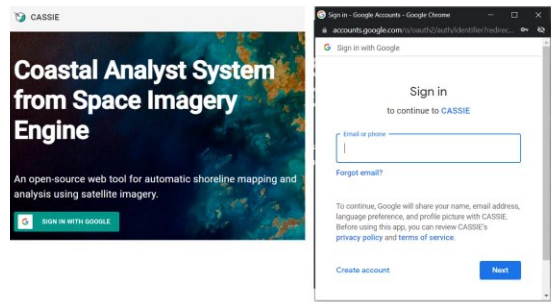

Figure 2: CASSIE authentication screen

4.1.2. Satellite selection

User has to choose which data source will be utilized: Landsat or Sentinel. It is not possible to mix both data sources as the images contains different configurations. It is so because all operations performed by GEE are based on a specific collection.

4.1.3. Area of interest selection

Using google maps API, the user can draw over the map an area of interest. This area can be defined manually using the mouse cursor or even importing an KML file [9]. The KML file import is particular useful to run several study cases over the same region of interest.

4.1.4. Defining a period of dates and cloud tolerance

After choosing the satellite and the area of interest, the user has to define the period of desired images, defined based on a start and an end date. At this point, CASSIE also assists in the filtering by asking user about how much of cloud presence is tolerated per image.

4.1.5. Filtering images

Based on previously filtering criteria, CASSIE brings all the images in a thumbnail format, already clipped based on the area of interest. User manually filter the images to be processed by selecting them This step is important because sometimes there are images with low quality and they can prejudicated the output results.

4.1.6. Draw baseline of reference for shoreline analysis

The baseline is a line of two or more points that user has to set in a region near to the land and water border which will be used by CASSIE to calculate the shoreline deviation from this line.

Alternatively, the user can also import a KML file that contains the geometry and location of this baseline.

4.1.7. Parametrizing

The last step before processing, the user has to parametrize values to be utilized for shoreline analysis, including extension, distance and threshold.

4.1.8. Results and transactors presenting

At this point, the processing begins and it can take more or less time depending of the amount of images filtered to be processed. When CASSIE concludes its processing, it then prints several transactors at the map and also a table that presents details about each transactor statistics.

4.2. Technical architecture

CASSIE architecture is composed by a frontend web application that interacts with remote web services provided by cloud-based APIs. An overview about CASSIE technologies and dependencies are presented in Figure 3.

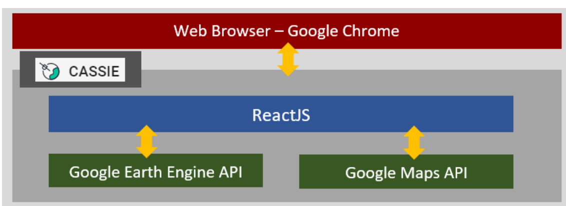

Figure 3: CASSIE overall architecture

As presented, the main dependencies from CASSIE are the GEE and Google Maps API. From these APIs, the Sentinel and Landsat images can be accessed and processed in many ways. More than providing access to satellite data, it provides a set of methods for image processing and filtering, which accessing in the handling of this large dataset. The importance of GEE in the feasibility of these kind of processing is that all the data access and processing are performed in Google Cloud in a distributed manner. Aiming to provide to users a simple way for interacting with the areas of interest and visualization of images within a context, the Google Maps API provides a set of resources. It supports the user interacting for drawing areas of interest, seeing processed images and shapefiles by printing the object layers of interactive maps through web browsers. Based on these technologies, CASSIE acts a manager from remote and distribute services, then, with the assistance from ReactJS (https://reactjs.org/), CASSIE handles requests to be performed by google cloud over GEE and present its outputs in a graphical interface through Google Maps API.

5 Evaluation

The tool has been utilized for more than two years and constantly improved and updated based on user's feedback. Statistics of usage has been systematically collected by google Analytics software since March 2022, and until October 2022 it has been registered 7,2 thousand pages accesses. Beyond feedback received it has included some improvement suggestions as the possibility of shapefile importing through a KML file and reports of some regions which the tool did not provides the complete output, especially for remote areas where images sometimes are not so accurate. Such feedbacks were already incorporated to the tool providing a more robust processing in terms of dealing with expectations.

6 Conclusion

Using the satellite images from a dataset of more than thirty years, CASSIE is being able to provide a consistent shoreline analysis. The processing of such images can be performed in a feasible time with the assistance of the distributed and cloud-based APIs provided by GEE services. The results of this work show how software tools design for end users can reach wide audience and being a feasible tool in comparison of another similar tools for shoreline analysis with demands more technical interaction. For future work CASSIE, is being improved to include more modules such as the Bathymetry which based on satellite images and training data is able to estimate the water deep.

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