

digisat: Sentinel-2 Resolution Enhancer



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1. Motivation and objectives

In the domain of GIS, the spatial properties of an image especially resolution plays a major role in the accuracy of outcome for any geospatial use-case. We have a lot of satellites that provide both coarser and high-resolution data. A coarse resolution captures comparatively larger area as compared to high-res sensors. One such sensor, Sentinel-2 has been providing high quality data for the entire planet for more than a decade now. However, due to its low resolution data of Multispectral bands (except RGBN), the insights are not as accurate because some bands are at 20m and 60m as well. At this resolution, the image is nothing but a space of mixed pixels which often become a problem in doing spatial analysis using indices.

To counter this, based on some research work done previously in the paper [Super-Resolution of Sentinel-2 Images: Learning a Globally Applicable Deep Neural Network](#), it is possible to train a deep learning neural network of CNN that can learn the spatial properties of the high resolution bands at 10m and enhance the resolution of lower resolution bands. This allows us to resolve all the MS bands to 10m.

In this tool, as an additional step to the already trained the model, because of the lack of GUI to the current offering of the model and its interpretation of the output is not feasible for the normal user as it requires a lot of programming knowledge and high-resource infrastructure, I was able to deploy this model to production with an GUI layer with a map and the ability to draw any AOI on it. The entire process has been automated end-to-end i.e. Drawing AOI to rendering the enhanced outputs in browser allowing anyone to get an enhanced version of the MS bands of almost any place.

Using this tool, a user will be able to accurately perform:

- Precision agriculture analysis, for eg. Calculation of sugar concentration, LAI, stress etc.
- Land use classification using SWIR Band
- Crop health monitoring and moisture analysis using SWIR Band
- Geological transformations using SWIR Band like faults
- Coastal area study using Aerosol Band
- Enhanced cloud removal using Cirrus Band

2. Design

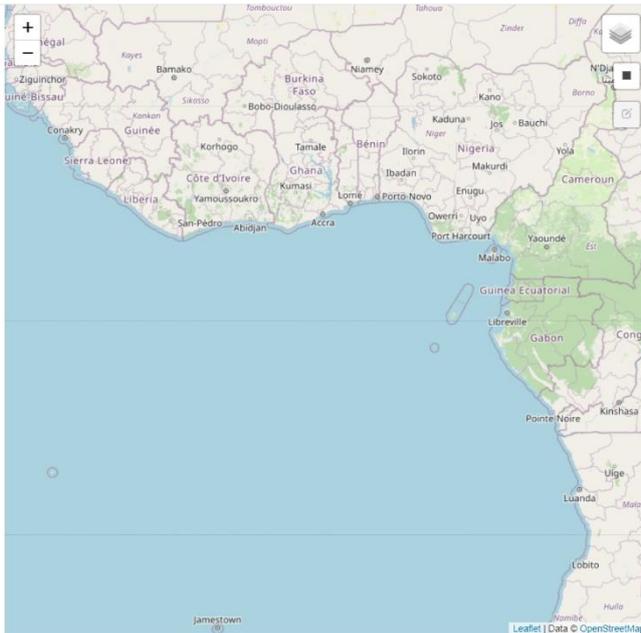
This tool is built on Python and Javascript with 3 major components:

1. **Model Development:** This phase is independent of the web application and involves training of a CNN Network with the sentinel-2 images. It is to be run separately as it will provide us the necessary model file through which we'll make future predictions. The gist of the modelling approach is to downsample the sentinel-2 bands to for eg. 20m > 40m and 60m > 360m and then running the CNN to learn the spatial properties.
2. **Web App (Backend):** The backend of app is build using Flask, a Python library to serve and host web applications. It also uses "sentinelsat" library to search Sentine-2 tiles from Copernicus database for any given AOI. The application has the following endpoints:
 - a. **/download** -> This function takes in a GeoJSON as an input and is passed to the sentinelsat library to download the relevant tile
 - b. **/resolve** -> It is two stage process
 - i. Run the model on the given tile using "tensorflow-gpu" library of Python
 - ii. Convert the output raster to COG (Cloud Optimized Tiff) using GDAL for faster rendering
3. **Web App (Frontend):** The frontend of app uses majorly Javascript, HTML and Bootstrap
 - a. **Javascript:** We use a leaflet based map library for loading basemaps in browser
 - b. **HTML/Bootstrap:** For basic structure of the page

Application Flowchart

The following sequence of images show the order in which the application works. Due to resource constraints, the end-to-end process for any AOI takes around 30 minutes to complete

1. The app interface loads something like this. On the left side we have the **leaflet map** where a user can draw an AOI and on the right we have a table showing some pre-processed outputs across three locations



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Sentinel-2 Pan Sharpening | Approx. TAT: 25 Min

Rendered Examples			
Place	Raster Type	Bands	Resolution
Lisbon, Portugal	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m
Bangalore, India	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m
Sacramento, USA	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m

2. After drawing the AOI, the application will start downloading the tile from Copernicus



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Rendered Examples			
Place	Raster Type	Bands	Resolution
Lisbon, Portugal	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m
Bangalore, India	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m
Sacramento, USA	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m

Downloading From Copernicus | Approx. Wait Time: 15 Minutes...

3. Once it's downloaded, the model will then run for this tile for enhancing all the bands using GPU



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Rendered Examples			
Place	Raster Type	Bands	Resolution
Lisbon, Portugal	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m
Bangalore, India	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m
Sacramento, USA	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m

Downloaded Tile

S2A_MSIL1C_20211024T113321_N0301_R080_T29SMC_20211024T134425

Enhancing Tile From 20m/60m To 10m

- Finally, it will provide us the links to each of the tiles, raw and enhanced. For this app, only a small sample is provided for visualization, namely the band combination of [B1, B5, B12]. This provides an avg. resolution of **33.33m** as each band is of **60m/20m/20m** respectively. The final enhanced raster will be of 10m exactly for the same band order/combination



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	Enhanced	B1, B5, B12	10m
Bangalore, India	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m
Sacramento, USA	Original	B1, B5, B12	~ 33.33m
	Enhanced	B1, B5, B12	10m

Download Samples

Raster Type	Band Order	Resolution	Visualize
Original	B1, B5, B12	~ 33.33m	Original
Enhanced	B1, B5, B12	10m	Enhanced

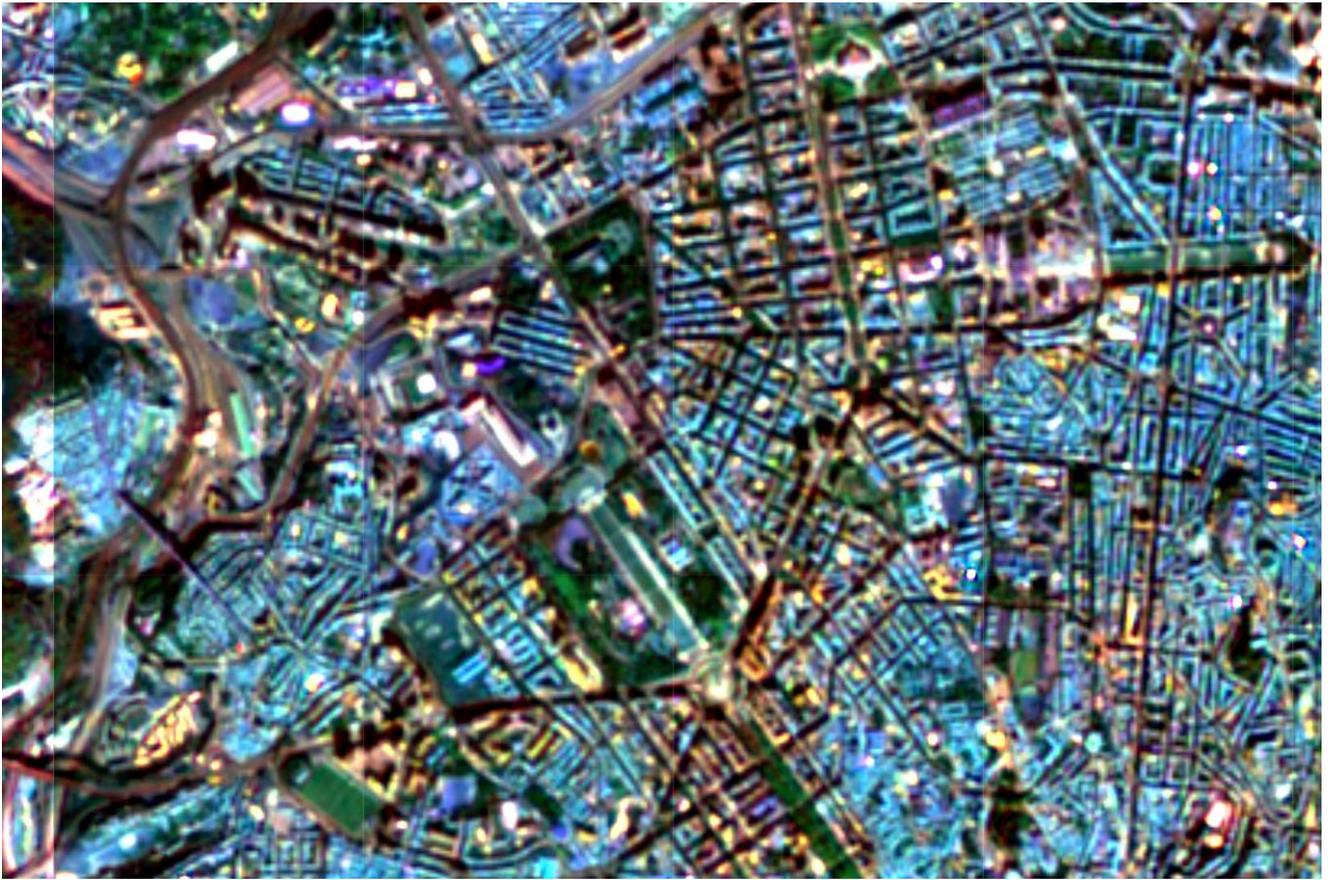
5. Final Outputs Comparison

a. RAW Image



The NOVA IMS Locality in B1/B5/B12 at 33.33m

b. Enhanced Image



The NOVA IMS Locality in B1/B5/B12 at 10m

3. Reproducibility

Github Link: <https://github.com/purijs/Sentinel-2-Superresolution>