

Monitoring of Photovoltaic Systems Based on Satellite Products

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Abstract

The observation and control of new technologies is of utmost importance in the age of progressive technological processes. Satellite images and software products could be of great benefit in this research. Satellite images could be used for analysis of the most suitable places for the installation of photovoltaic systems. This will allow maximum use of free areas with infertile soils. The efficiency of photovoltaic systems is dependent on the angle of exposure to sunlight. With using of satellite products they could be installed in the most appropriate places.

In this century a significant problem is the global pollution. Through the satellite earth observation, the most polluted areas could be monitored. Photovoltaic parks are areas of high fire risk because of the heating from the sun. That is the reason, it is necessary to monitor them constantly for emergency management.

With satellite images and software products, we could make a spatial database, which could be useful for development of renewable energy sources.

Keywords: Photovoltaic Systems, Satellite Images, Spatial Data, Artificial Intelligence

1. Introduction

Global pollution and significant reduction of conventional energy resources are changing our world. Renewable energy, especially photovoltaic (PV) systems are with rapidly-growing capacity every year [1, 2].

We could use satellite images and software for observation the development of the PV Systems.

With our application, we make analysis for the most suitable places for placing the PV Systems. We could use the maximum of free areas. It is really important PV Systems to be friendly to agriculture.

Through this method we also monitoring the most polluted areas from conventional energy sources. These areas are with high fire risk. One of the most important advantage of this method is that it can be used in emergency monitoring.

With our software we could make a spatial database with all the PV Parks in the observed area. One of the major topics to be investigated in this field is monitoring of already placed PV parks, their capacity and also finding the best places for new parks where they are needed.

This field closely follows the paradigm of artificial intelligence and training it to work with satellite images. One of the primary benefits of this algorithm is to find broken panels in PV parks. This will save a lot of money and human resources.

2. Purposed method

The purposed method is to train an intelligent software which can recognize and monitor PV systems and PV parks in the observed area. A satellite images are downloaded free from Copernicus Open Access Hub [3], satellite Sentinel 2.

For the study were selected photos of photovoltaic parks build in Karadzhalovo and Dolna Mitropolia, located in Bulgaria.

2.1. Algorithm of a satellite images training sample

In the block scheme (fig.1) is given the algorithm of an image processing before training sample. For the processing of a satellite image was used specialized GUI software "Sentinel Application Platform" [SNAP] [4]. The purpose of this procedure is to convert the image in RGB channels with necessary bands: B4, B3, B2 (fig. 2.1) a combination for true color imagery from Sentinel 2. RGB channel correspond as follow: **Red** - Defines the mathematical expression for the red channel; **Green** - Defines the mathematical expression for the green channel; **Blue** - Defines the mathematical expression for the blue channel.

The image is resampled by pixel resolution in meters (20m) and subset with reflectance in band the observed area (fig.2). The transformed image is saved in "tif.file" to process to the next specialized geographic information system software ArcGIS[5].

Once the image processing is started through the ArcGIS GUI, via Arcgis Training sample manager tool a different kind of objects are marked to be defined with polygons (fig. 3). Different colors of polygons defined areas as follow: fields, soils, vegetable crops, roads, settlements, water and PV Parks. Supervised and unsupervised classification of the

images is made after training the polygons as shown on (fig. 4).

Algorithm of a satellites image processing for training sample:

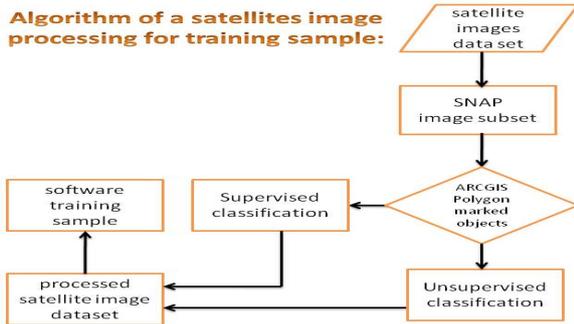


Fig 1. Block scheme of algorithm of a satellite images training sample

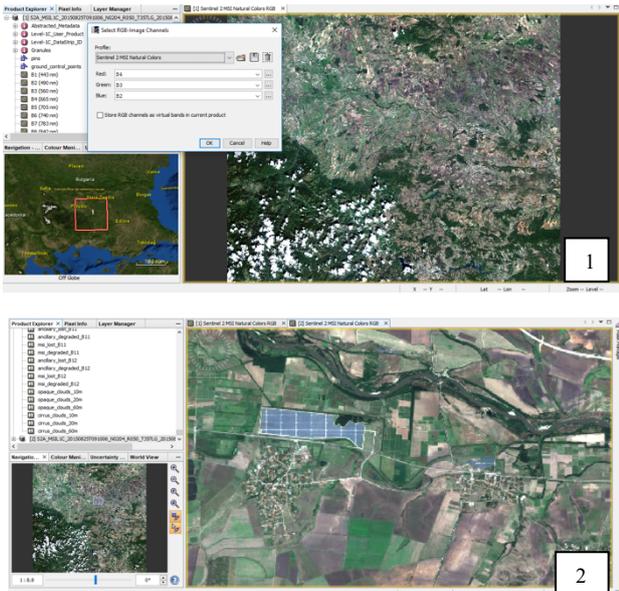


Fig 2 - 2.1. RGB image band conversion, a combination for true color imagery from Sentinel 2. 2.2. Resampled and subset image of the observed area.



Fig 3. Marked and defined objects with polygon

ID	Class Name	Value	Color	Count
1	fv	1		161
2	veg	3		502
3	soil	5		957
4	water	7		91
5	grass	19		33
6	urban_1	28		100
7	field	34		99
8	road	37		40
9	grassland	44		10

Fig 4. Supervised training manager

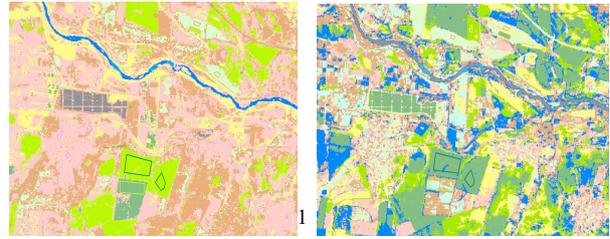


Fig 5. Supervised and unsupervised classification of Karadzhalovo, Haskovo, Bulgaria

The following methods were used for creating the calcifications: ArcGis Interactive supervised classification tool for supervised and Iso cluster unsupervised classification for unsupervised. Unsupervised calcification tool uses the formula [6] shown on (fig. 5)* for creating the results, where:

$$Z = \frac{(X - old\ min) \times (new\ max - new\ min)}{(old\ max - old\ min)} + new\ min(1)$$

Fig 6. Iso cluster unsupervised classification*

The idea for creating an application that helps people detect and monitor different objects, was born when we decided to take part in the Copernicus hackathon in Sofia. We called it "[Rocket Image Processor](#)". The application was created as PRC (proof of concept) so it has a lot more work till it becomes ready to ship product.

2.2. Application Overview

Currently the application has pretty simple functionality. Right after the user loads the page there appears a dropdown list where he can choose what kind of predefined objects are going to be detected (fig. 7).

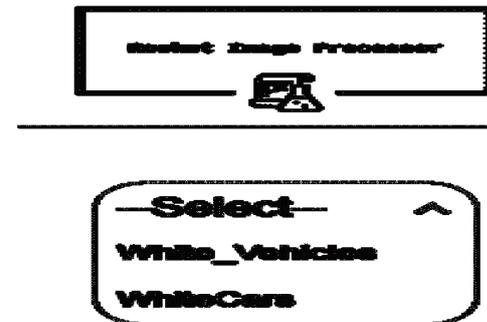


Fig 7. "[Rocket Image Processor](#)"

Right after choosing an option the user can upload a single image using Drag & Drop or browsing the file system (fig. 8).

(fig.6) Z = the output raster with new data ranges;
X = the input raster;
oldmin = the minimum value of the input raster;
oldmax = the maximum value of the input raster;
newmin = the desired minimum value for the output raster;
newmax = the desired maximum value for the output raster.

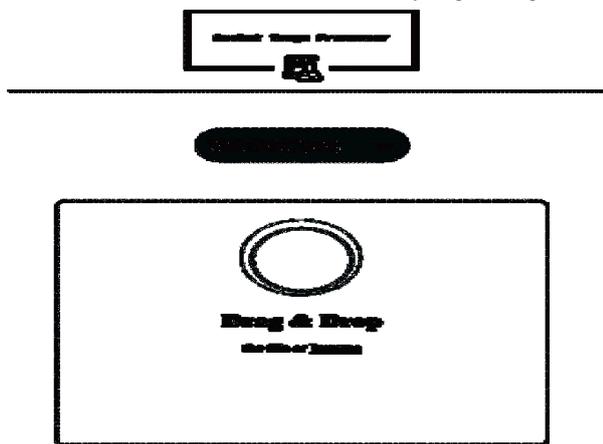


Fig 8. Uploading a single image using Drag & Drop

After the image is being processed the user can see a table where are listed all the matches with corresponding coordinates. Using the coordinates we can easily locate the target objects and calculate other parameters like area, using the image resolution.

The data are presented in Fig. 9 – Spatial data for PV Systems, located in the territory of Bulgaria. After we found every single PV park in Bulgaria, we use QGIS[7] software to make spatial database with the exact coordinates. Our results are demonstrated in a map with every PV park in researched area. Behind the map, we have whole database table with exact coordinate of every object.

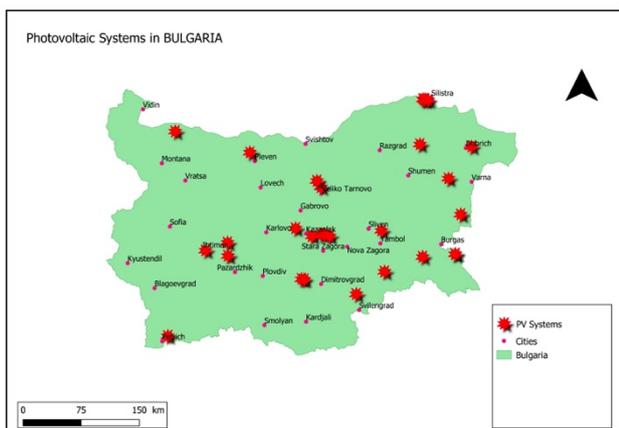


Fig 9. Spatial Data map – PV Systems in Bulgaria

Challenges:

During the development process we faced two major challenges:

- Finding images with high resolution – In order to create good samples for detecting objects and machine learning classifiers we needed images with resolution ≤ 0.3 meters per pixel. To solve this issue we ended up using some ready datasets which are distributed free. We used websites dedicated to machine learning datasets like Kaggle [8]. Most of the datasets for creating high accurate samples were taken from drones from height about 100-150m and resolution ≤ 0.3 meters per pixel.
- The time – the time was our biggest enemy since we had less than 48 hours to create something working. So

for the **PRC** we decided to go with a ready to use image processing service Nanonets [9]. It is a **Machine Learning API** that provides the following functionalities:

- Object Detection
- Image Classification
- Image Tagging
- Image Segmentation

The web interface was created using Vue Js framework.

Usage:

In the context of inspecting and monitoring PV modules, using Computer Vision algorithms will help to determine different defects like disconnected panels, thermal hotspots to diode failures faster. The custom created models are capable of analyzing entire solar farms within a couple of hours which would otherwise take weeks for domain experts. For example if the inspection is done manually and the average speed is 6000 PV modules/man/hour, using computer vision software can easily process up to 200,000 PV modules/hour and reduce costs over 3 times. This speed can save millions of dollars in module replacement costs by identifying faulty panels faster within the warranty period.

Outcomes:

Using such kind of software boosts efficiency greatly, both in terms of speed and in terms of accuracy. Using computer vision algorithms we can build custom models, which can accurately identify and locate different objects and defects faster compared to using domain experts.

Future:

Taking into account it is **PRC** there are a lot of things to change in the application but the 2 main things to start with are:

- Using customized algorithms for image processing
- Improving user experience

3. Results and discussion:

Our results cast a new light on usage of satellite images and special software for them. This performs well, giving good results. We showed that it is possible to solve a lot of environmental issues through processing of satellite images. We could observe whole processes and uninvestigated areas for specific problem, such as renewable energy resources.

The results confirm that is a good choice for finding specific objects in selected area and also we could see and explore the Earth from different angle. Our limitations in this study are from the resolution of images. With high resolution and special software, we could find every object we want in specific area.

4. Conclusions:

For the decades, one of the most popular problem is saving the resources of the Earth.

It will be important to keep our planet safe and clean in the Future.

The renewable energy is the future for energy resources in the world.

The results provide basis for 24-hour observation of PV Systems through this application and Sentinel Satellite Products.

Overall, our results demonstrate a strong effect of not only environmental issues but also good business strategies. Future research should consider the potential effects of monitoring the PV Systems more carefully, for example to prevent accidents, finding the best places for placing the PV parks and also using the maximum capacity of free areas with barren soil.

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