Deterministic Detection of Photovoltaic Panels in Aerial Images

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ICSC
SPOKE 2

Emiliano Tramontana, 19.12.2023

Motivations

- Aerial images can be used to estimate the amount of green energy production expected in a community
- For this, it would be necessary to detect (and then measure) the photovoltaic (PV) panels from aerial images. PV panels can be recognised on the basis of colours
- A great amount of colour gradations are represented in a PV panel, and some of the colour gradations in PV panels are also found elsewhere
- Research objective: *can we obtain PV panel detection without resorting to a machine-learning approach?* [Yes] The expected benefits are: explainability, fast execution (no training)

Other Approaches for PV Detection

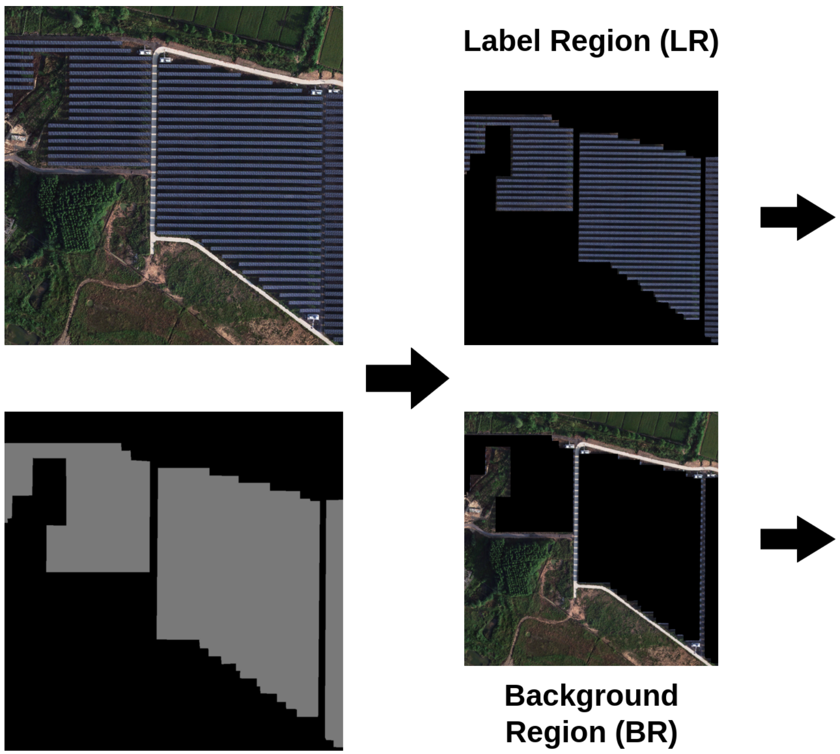
- Employ CNN-based architectures
- Require large annotated datasets
- Require relevant computational resources for training
- Lack of explainability

Proposed Approach

- Phase 1: Analyse colours in images, find background colours, very dark or very light PV panel colours
- Phase 2: PV panel colour extraction (from an annotated dataset)
- Phase 3: PV panel detection
- Phase 4: Denoising, find and exclude pixels that were marked as PV colours, however represent less than a third of the pixels in a moving tile

Phase 1: Classification of images

- Phase 1a: RGB colours were collected, and if a colour was in both labelled region (LR) and background (BR), then it was considered a PV panel colour if it was found more often in LR than in BR



LR colors

RGB	Count
(58, 63, 80)	3897
(58, 63, 81)	3810
(57, 62, 80)	3775
...	...

BR colors

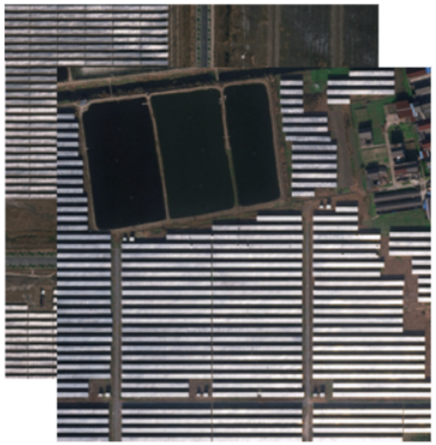
RGB	Count
(40, 45, 44)	50088
(40, 45, 45)	49231
(39, 44, 44)	45832
...	...

Phase 1: Classification of images

- Phase 1b: using HSL (Hue, Saturation, Lightness) colours, images where panels had a high number of dark pixels (n > half of total, lightness < 0.2) were removed
- Phase 1c: using HSV (Hue, Saturation, Value) colours, images where panels had a high number of saturate pixels (n > fourth of tot, satur > 0.33) were removed

dark panels

light panels



detectable panels

Phase 2: Colour Extraction

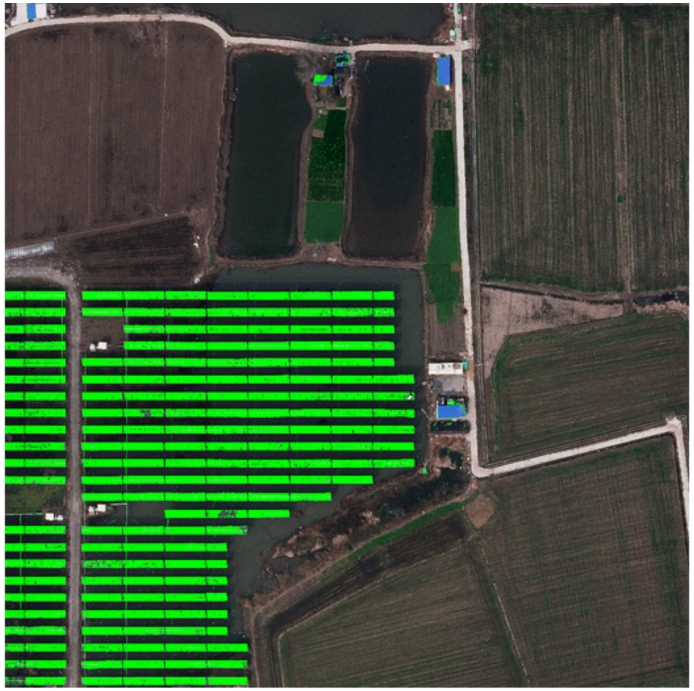
- Starting from the set of colours found in the labelled region (LR), the subset of LR colours that are also frequent in the background (BR) were removed
- Then, from the set of PV colours remained, the dark colours and the saturated colours were removed
- The result is a set of colours (as RGB values) typical of PV panels

Phase 3: PV Panel Detection

- The set of PV colours is searched in an unknown image, and the pixels found are marked in green

panels

pixel found for panels



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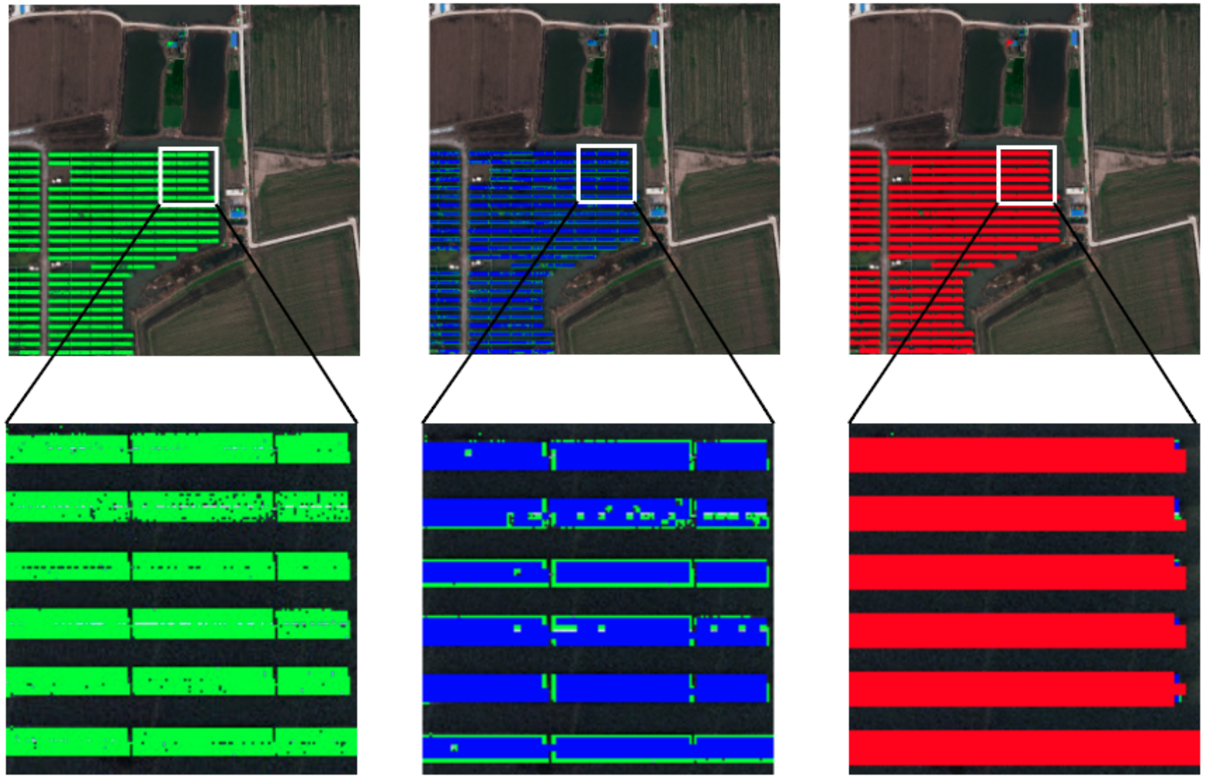
Phase 3: PV Panel Detection

- A moving tile 5x5 (blue) was overlapped and when more than 75% of tile pixels are green then the whole tile becomes blue; similarly for a tile 11x11 (red)



Results

Dataset	Size	Accuracy	Precision	Recall	F1 Score	IoU
Ground	458	0.963	0.918	0.901	0.897	0.833
Cropland	146	0.971	0.931	0.938	0.931	0.877
Grassland	42	0.952	**0.953**	0.881	0.912	0.844
SalineAlkali	53	**0.982**	0.913	**0.958**	0.934	0.878
Shrubwood	77	0.975	0.934	0.956	**0.944**	**0.897**
WaterSurface	140	0.974	0.915	0.928	0.917	0.852
max in [30]		0.981	0.960	0.903	0.931	0.877

Phase	Average Execution Time per Image
Image Classification	2.42 s
cPV Colours Extraction	1.63 s
PVs Detection (3 passes)	9.25 s
Image Denoising	3.16 s

Conclusions

- The proposed solution determines the range of colours that are typical of PV panels, then analyses images to locate such typical colours and find boundaries of PV panels by considering both the colours and their density
- The proposed approach is deterministic, robust, and much faster than other previous neural-network-based approaches

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Publications

- D. Marletta, A. Midolo, E. Tramontana. Detecting Photovoltaic Panels in Aerial Images by Means of Characterising Colours. Technologies 2023, 11(6), 174; https://doi.org/10.3390/technologies11060174