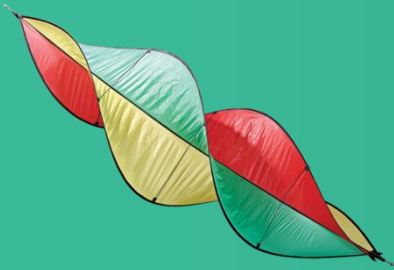# Detection of Photovoltaic Installations in RGB Aerial Imaging

A Comparative Study

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Overview

- <u>Introduction</u>

- Dataset

- Suggested approach
  1. Pixel based colour classification using SVM
  2. MSER based colour segmentation and shape analysis
  3. Boosted cascade of weak classifiers
  4. Aggregate channel features

- Results

- Discussion and conclusion

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Introduction

- Solar panels = resource of non-polluting green energy
- Subsidized and encouraged by both governments and electricity grid administrators, in the form of tax reductions

- However, this also gives raise to fraud with the registration of solar panel installations

- Our client, an electricity grid administrator, wants to use computer vision to track down photovoltaic solar panel installations in RGB aerial imagery

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Introduction

- Challenges in fully automated solar panel detection in RGB aerial images
  - Few distinct visual features like shape and colour
  - Limited resolution of 25cm/pixel
    - Open-access data from FGIA
    - Size single panel = 9 x 7 pixels <-> 1 x 1,5m
  - Specular reflections due to material used
  - Varying orientation (S, SE, SW)
  - Different roofs' slants (30°, 45°, 60°, etc.) -> deformations
  - Different solar panel types (mono-, polycrystalline, full black, etc.)

Introduction

- Goal:
  - Fully automated detection of solar panels
  - Given the aerial imagery available
  - With a high certainty

- End game = reduce the enormous amount of manual labour to locate solar panel installations for fraud detections

- But robust detection can be combined with tons of other sources of knowledge like electricity distribution, population density, etc.

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Dataset

- Freely available medium scale aerial footage from FGIA (Flanders Geographical Information Agency) with a resolution 25cm/pixel

- Training data
  - 2.500 manually annotated solar panels
  - 150.000 random negative samples

- Test data
  - Aerial area of 2 x 2 km of city of Sint-Truiden
  - 8.000 x 8.000 pixels -> bicubicly upscaled to 16.000 x 16.000 pixels
  - Ground truth of solar panel installations (multiple panels)
  - Annotated by bounding polygons

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Suggested approach:
Pixel based colour classification using SVM

- Pixel classification of internal solar panel pixels (blue-grey range)
- Separate 1.000 panel pixels from 2000 randomly selected non-panel pixels in HSV colour space
- Linear SVM kernel

- Threshold on the output certainty of each pixel given by the trained SVM

- Opening and closing operators used to remove noise, followed by contour detection and filling for clean result

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Suggested approach:
## MSER based colour segmentation and shape analysis

- Systematically increasing a threshold on the grayscale pixel values (by only taking the blue channel) to create a set of sequential binary images
- Look for regions that stay stable over different thresholds and approximate by their fitted ellipse.

(a) blob candidates by MSER

(b) discarding blobs of incorrect size

(c) axis ratio deviating maximally 30% from the ideal 1.5:1 ratio

(d) HSV colour segmentation on the remaining blobs


(a)   (b)

(c)   (d)

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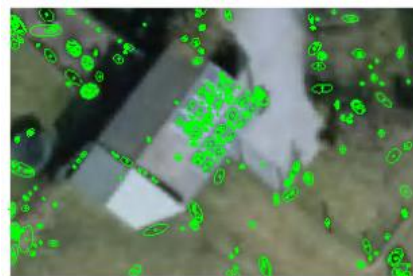
Suggested approach:
Boosted cascade of weak classifiers

- Using machine learning to model the solar panel object class

- Choice: AdaBoost to built cascade of weak classifiers
    - Look at texture and structure of an object class -> local gradients
    - Using local binary pattern feature descriptors
    - Normally only on grayscale images but integrated partial colour knowledge using the blue color channel

- Disadvantage of technique is the single orientation model
    - Rotating input image
    - Full 360° detection capabilities by warping back detections in a rotated input image

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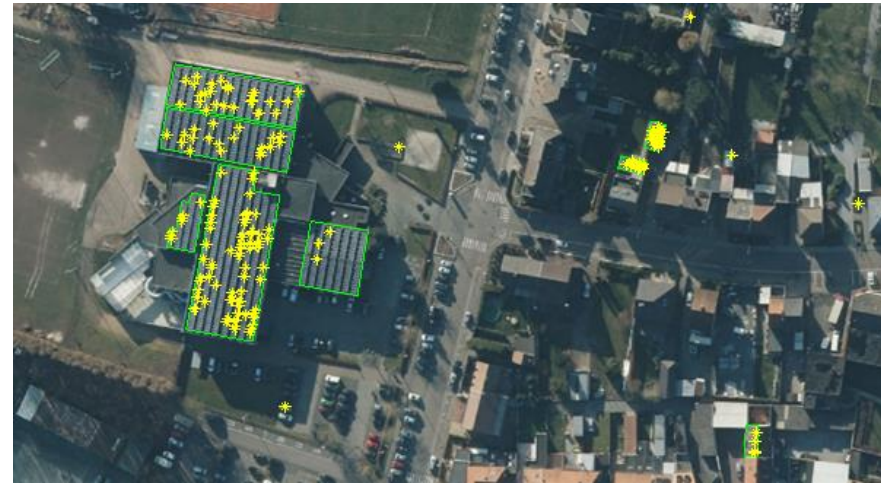
Suggested approach:
Aggregate channel features

- Extension to previous technique, incorporating color information as a new feature channel

- Own internally developed C++ implementation of this framework available

- Features used:
  - Colour
  - Gradients
  - Gradient histograms

- Technique decides itself which feature is good to use from giant feature pool generate on each sample

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Results

- Comparison of 4 algorithms in processing time
  - Clear difference between basic and more advanced computer vision approaches
  - However, training a model only needs to be done once
  - Detection times highly depend on
    - Available hardware
   - Optimizations *(ACF did not contain parallelisation)*

Technique used	Training time	Detection time	System configuration used
HSV + SVM	10 sec	10 sec	Intel(R) Core(TM) CPU i7-4500U @ 2.4GHZ
MSER	0 sec	100 sec	Intel(R) Core(TM) CPU i7-4500U @ 2.4GHZ
Boosted Cascade	3.5 hour	10 min	Intel(R) Xeon(R) CPU E5-2630 v2 @ 2.60GHz
Aggregate Channel Features	36 min	6 hour	Intel(R) Xeon(R) CPU E5-2630 v3 @ 2.40GHz

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Results

- To compare algorithm efficiency we decided to use precision-recall curves. For this several steps are followed:

  - Downscale image to 4.000 x 4.000 pixels

  - Combine scores of detections on the same locations

  - On top of resulting score map, we apply a threshold
    - ➤ This parameter is varied to generate the PR curves

  - On top of the score map we apply
    - Dilation: make the detection centres as large as an average solar panel
    - Erosion: remove detections that are lonely and not grouped

  - The resulting binary image is used to compare to the ground truth polygon annotations

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Results

- Red dots = detection centres

- Green = ground truth areas

- Blue = detection output areas

- Combining those labels leads to a classification of all pixels
  - Cyan: true positive
  - Black: true negative
  - Blue: false positive
  - Green: false negative

- Visualisation for both VJ (middle) as for ACF (bottom)

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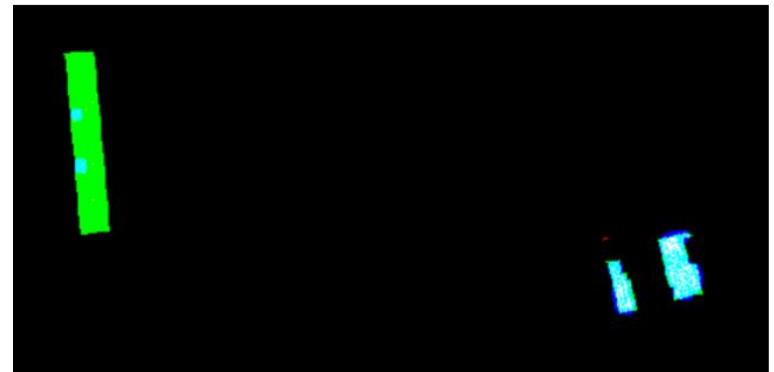
Results

- Precision – recall curves on Sint-Truiden test image
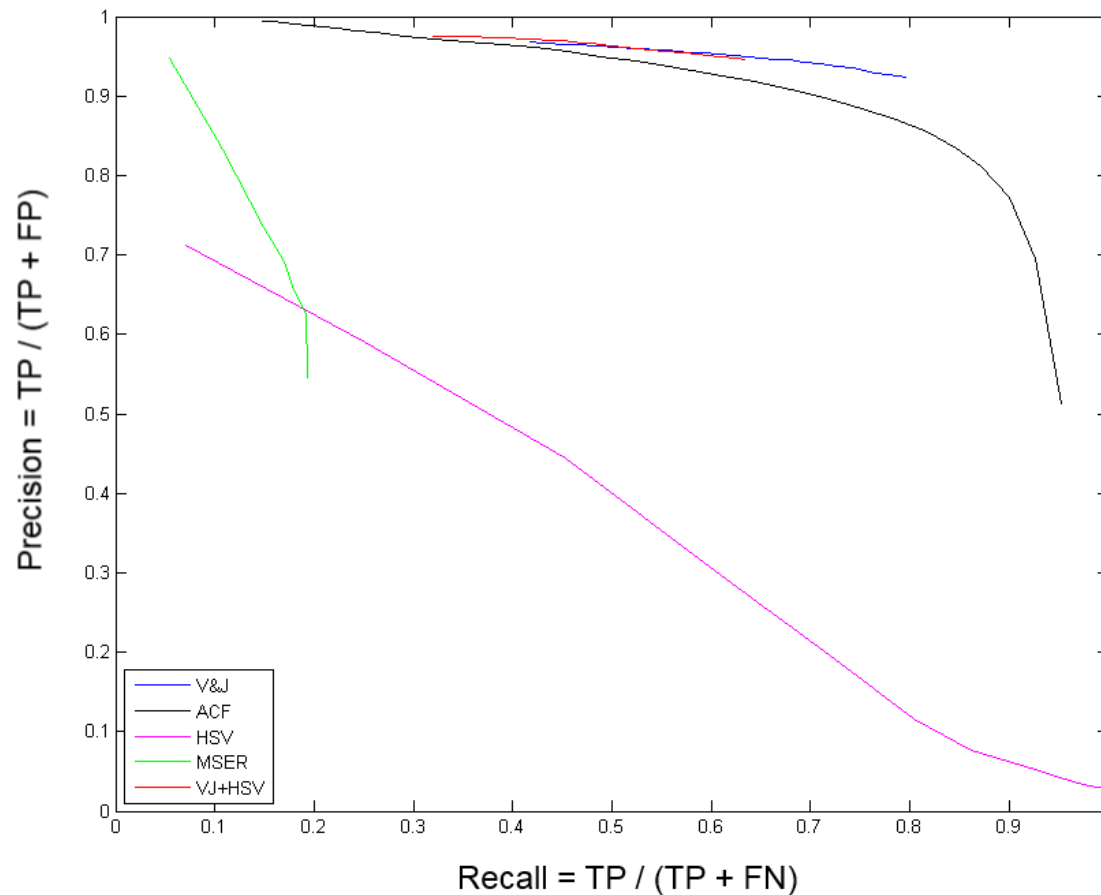
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Discussion and conclusion

- Pixel based segmentation only yields moderate results

- Smarter feature based techniques like MSER seems promising but have a fast drop in accuracy when considering larger areas

- Object categorization techniques clearly outperform the other technique

- Only downsides to object categorization
  - Collection of training data
  - Longer model training phase

- For a fully automated system, we achieve a precision of 93% at a recall of 80%, which is decent enough.

- Future work: take a closer look at CNN based detectors

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Thank you for your attention!

More info:

- http://www.eavise.be
- http://stevenputtemans.github.io

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