# Detection of manhole covers in high-resolution aerial images of urban areas by combining two methods

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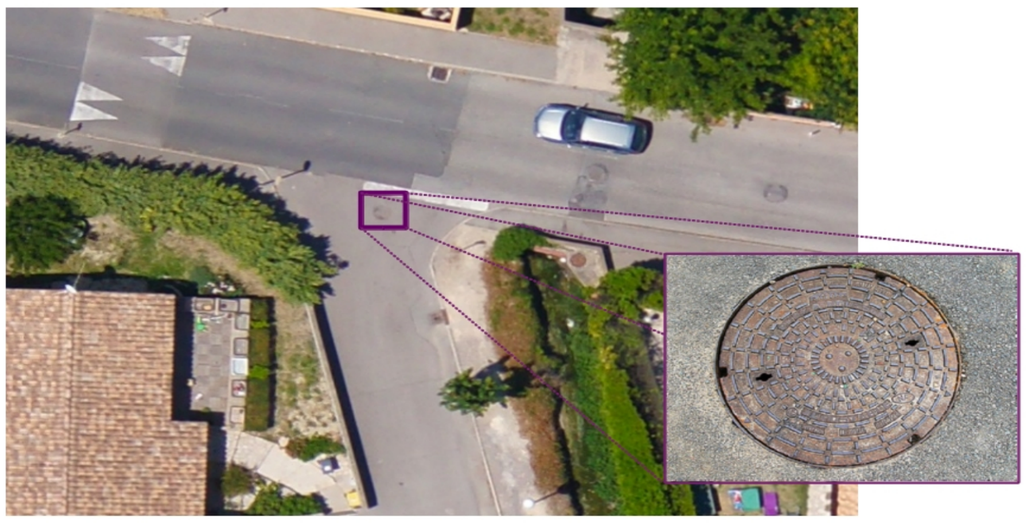
## Context

Over the past century it was common practice for public service providers to install, operate and repair their sewer networks separately. Even nowadays, it is difficult to find accurate maps of networks in cities of both industrialized and developing countries.

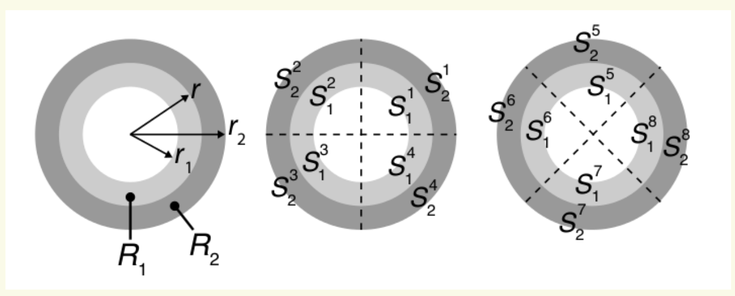


We propose to automatically detect manhole covers from aerial images in order to rebuild the network.

We use high-resolution aerial images :
- Size: 5,300 x 5,500 pixels,
- Resolution: **4 cm/pixel**,
- Manhole covers represented by **20x20 pixels**.

## Geometrical Approach

It is based on the method proposed in [1, 4] for the detection of circular patterns in a noisy and low contrasted image.
- Two annular regions $R_1$ and $R_2$ , each of which is divided into eight sub-regions.




- Three indices are computed to detect a circular pattern on a sliding window, using normalized histograms of each region/subregion.

- The similarity between two statistical distributions :

$$S(R_1, R_2) = \sum_{x=0}^{255} \sqrt{(p_1(x), p_2(x))}$$

- The second index is computed to avoid detection of linear patterns :

$$S_8 = \max_{j \in 1..8} \{ S(R_1, R_2^j) \}$$

- The last index assesses the uniformity inside the two main regions :

$$U(R_i) = \min_{j,\, j' \in 1..8} \{ S(R_i^j, R_i^{j'}) \}$$

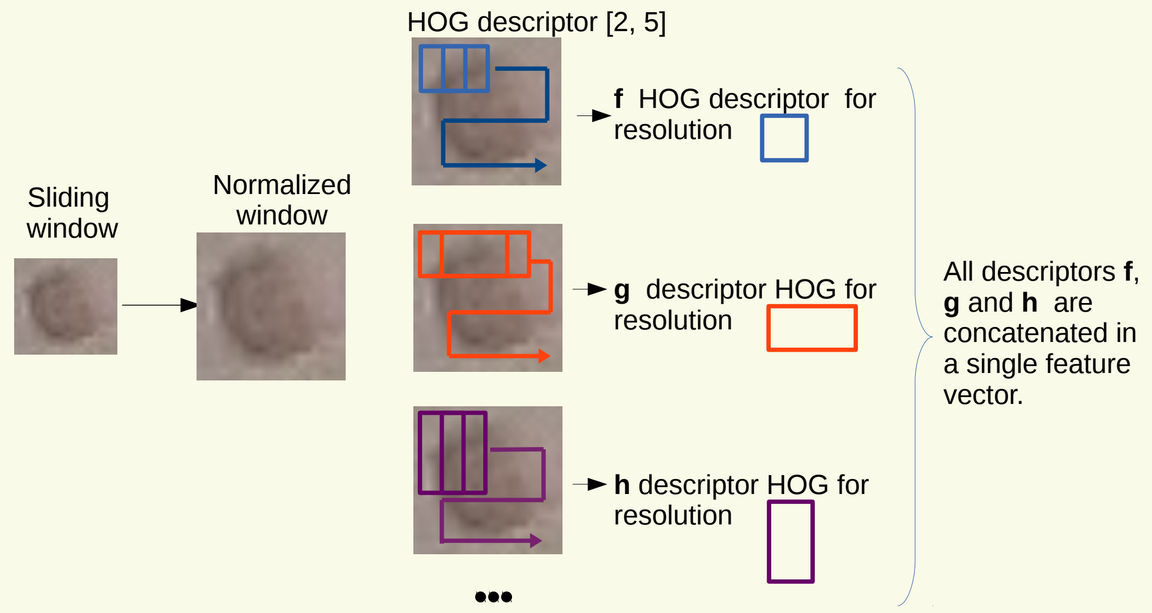
- The three indices are merged into a global index for circular pattern detection: $\zeta = (1 - \max\{S(R_1, R_2), S_8\}) U(R_1) U(R_2)$

The greater the value of ζ, the higher the likelihood of a circular pattern

**Drawbacks :**
- Each circular pattern is detected increasing the FP
- Can not detect rectangular manhole covers without any filters

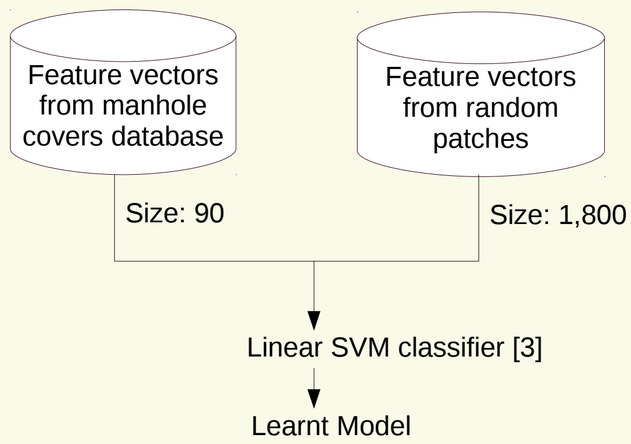
## Machine Learning Approach

**Feature extraction**




The size of the extracted feature is about 1,200.

**Learning step**




**Drawbacks :**
- A lot of false positives due to a small training database
- Descriptors are not optimized for circle detection

Circular detection filter

Histograms of oriented gradients

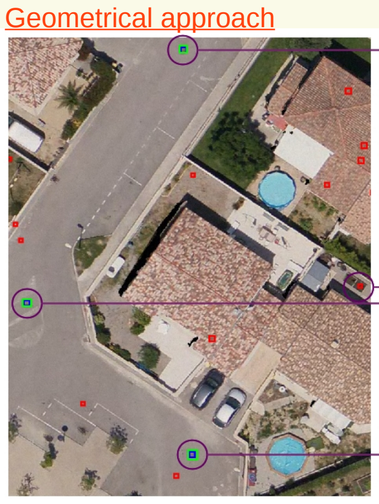
**Does merging both approaches improve the detection rate?**

Combined method

## Merging the approaches

False positives from geometrical approach and machine learning approach are not the same.
→ Merge the two results to reduce the error.

Geometrical approach

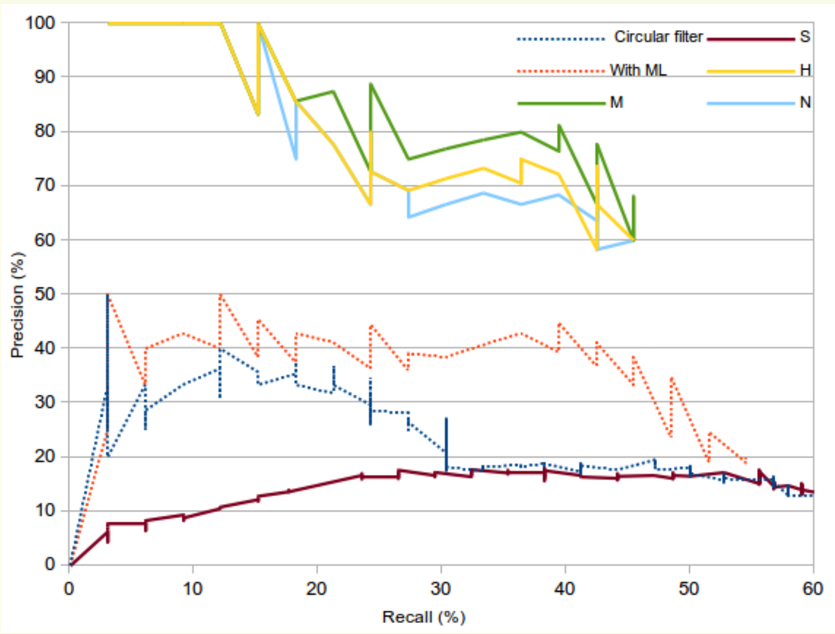


Machine learning approach

How to merge the two methods ?
- Sum function (S).
- Min (N) and max (M) function.
- Product function (H).

The max function gives the best results. The combined method doubles the precision to 80 % for a recall of 40%.

## Results

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