Automatic reconstruction of urban wastewater and stormwater networks based on uncertain manhole cover locations

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The context

Sud Ouest, 20/05/2016
Photo guillaume bonnaud

Case study 4

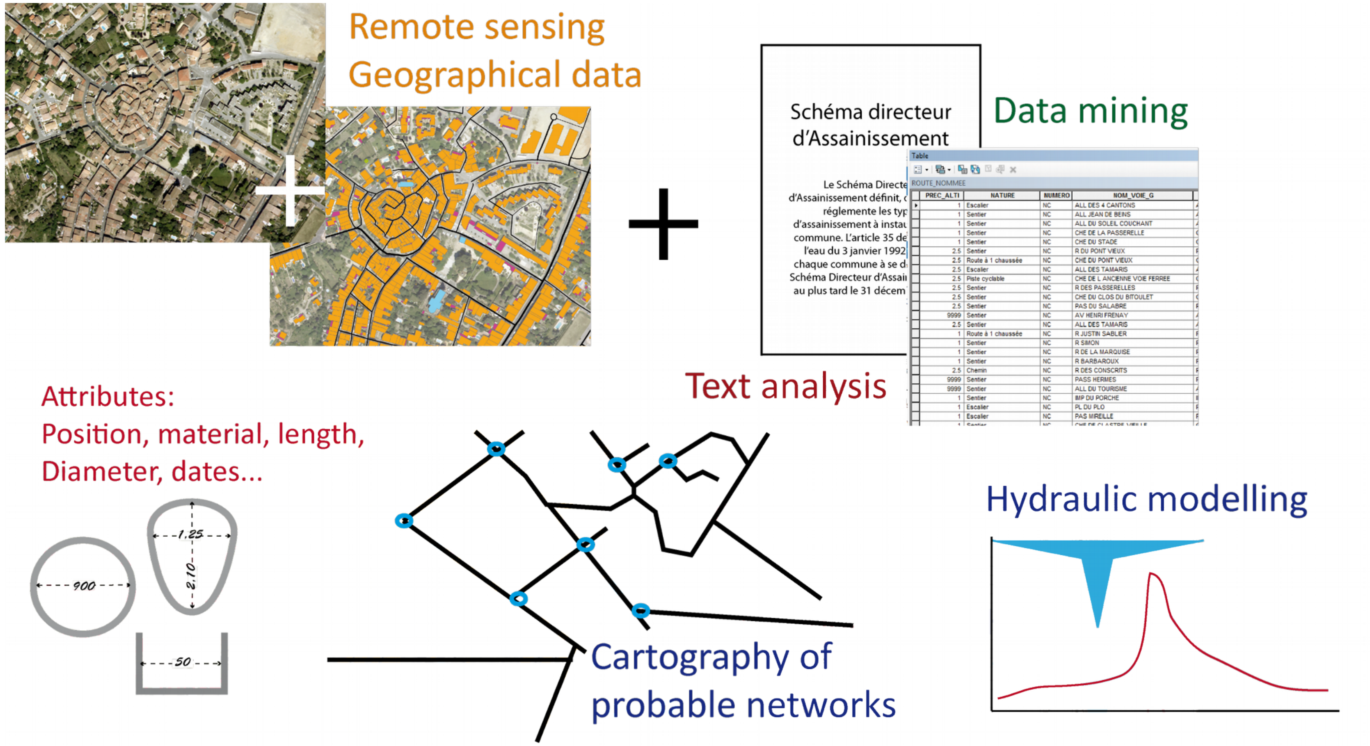
A worker suffered severe burns after drilling in to a low-voltage cable during work to install street furniture. The electrical cable had been moved, wrapped in plastic and encased in reinforced concrete during earlier works to redevelop the street environment. Its location had not been recorded by the contractor managing the work.

The cable should not have been encased in concrete. It should have been moved in consultation with the electricity distribution company.

HSG47 (3rd edition, 2014)

Lack of information about buried utility networks in both developed and developing countries => delays, increased costs, sub-optimal management of resources.

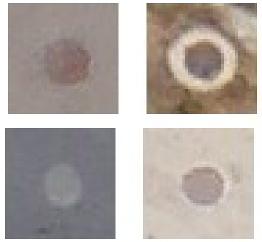
The context : THE Cart'Eaux project

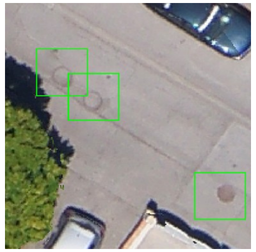


- Can an existing network be mapped based on manhole cover locations ?
- Optimal configuration may be determined (Walter, 1995; Afshar, 2007; Swamee & Sharma, 2013; Moeini and Afshar, 2012)
- Existing network layout may be reproduced if node to link or PE data is available (Allard et al., 2013; Blumensaat et al., 2012)

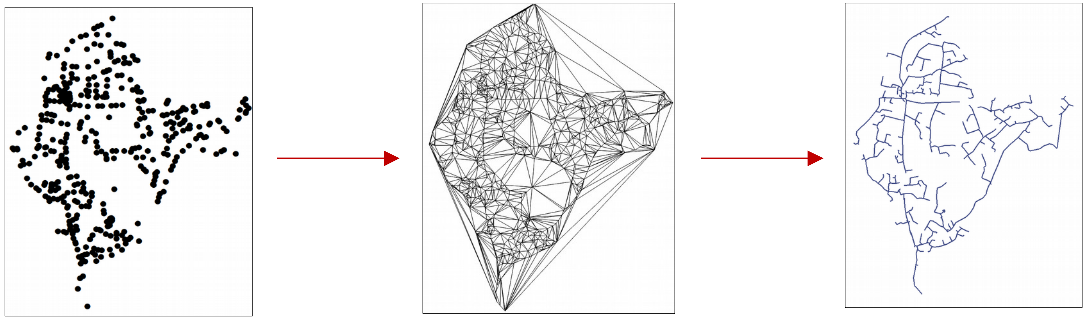
The methodology (1/2)

- Assumption: Manhole covers are a set S of georeferenced points $P_i(x_i, y_i)$ and the nodes of the network to be reconstructed. They can be detected using high resolution imagery (Pasquet et al., 2916; Commandré et al., 2017).

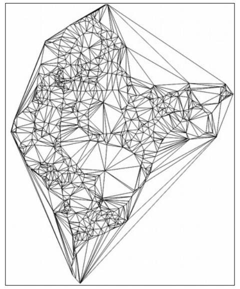




- Step 1: Compute a Delaunay triangulation based on the set S.
  - Assign $c(P_iP_j)$ i.e the "cost" for wastewater to flow from P_i to P_j. $c\left(P_iP_j\right) = -c(P_jP_i)$
- Step 2: Extract the Minimum Spanning Tree using Kruskal's algorithm (1956).



The methodology (2/2)



- Two examples of cost functions

⚠️ Assume surface and underground slopes to be parallel ⚠️

- $c_1(P_iP_j) = \left(\alpha \frac{l_{ij}}{l_{\max}} - (1-\alpha)\frac{\Delta_{zij}}{\Delta_{z\max}}\right) + \beta + \gamma$

l_{ij}: length of edge P_iP_j [L];

Δ_{zij}: elevation difference between nodes P_i and P_j [L];

α a weight to balance the influence of the length and the elevation ;

β, γ penalty parameters when the edge intersects a road or a building

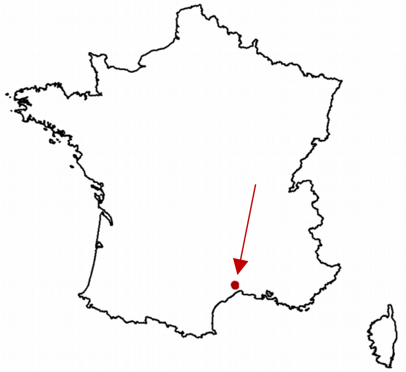
- $c_2(P_iP_j) = \alpha \frac{rank(l_{ij})}{max(rank(l_{ij}))} + (1-\alpha)\delta \frac{rank(|S_{ij}-S_m|)}{max(rank(S_{ij}-S_m))} + \beta + \gamma S_{ij}$:

S_{ij}: slope of edge P_iP_j [L.L^{-1}];

S_m : mean value of the interval [2 ‰, 7 ‰] [L.L^{-1}]

δ = 0 if the slope is in the interval, otherwise δ =1

Case study : Prades-Le-Lez (Southern France)



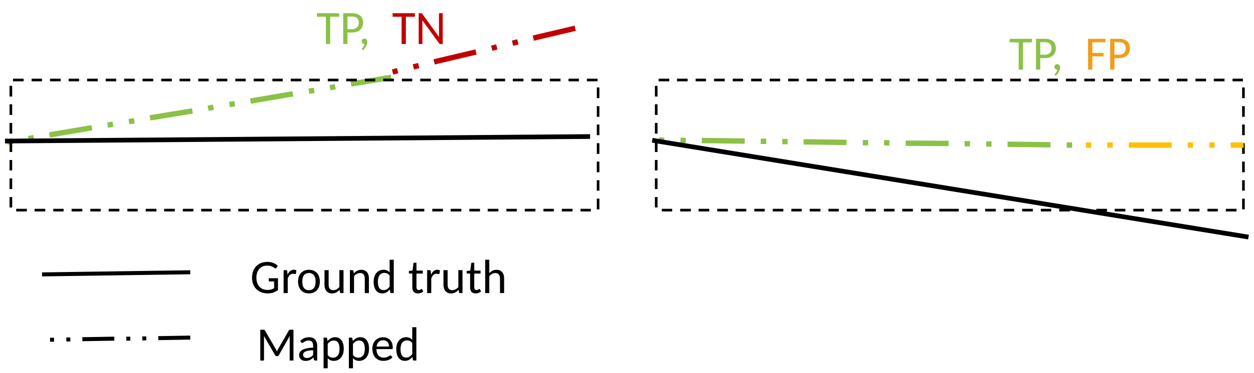
- 799 manhole covers and 23.45km of pipes (operator data).
- Geographical data base (DEM, roads, buildings) available through IGN.

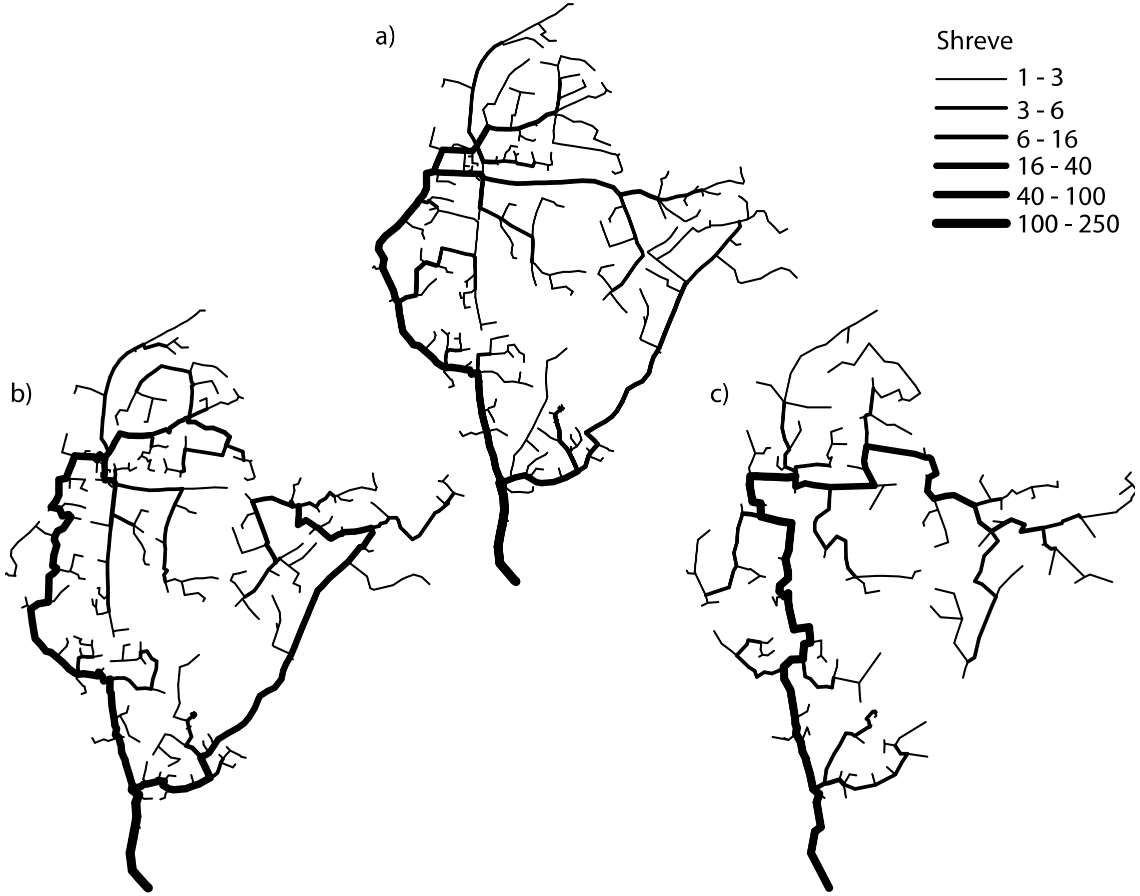
- Randomly select ½ of manhole covers to test the algorithm
- Assess and compare
  - Correctness, completeness, quality (Heipke et al., 1997).
  - Network hierarchy (Shreve, 1966).
  - Distance to the outlet (Allard et al.2013).

http://www.prades-le-lez.fr/

Results (1/3) : cost function 1

Cost function	Correctness	Completeness	Quality
All nodes	0.89	0.84	0.76
Half of the nodes	0.44	0.55	0.32

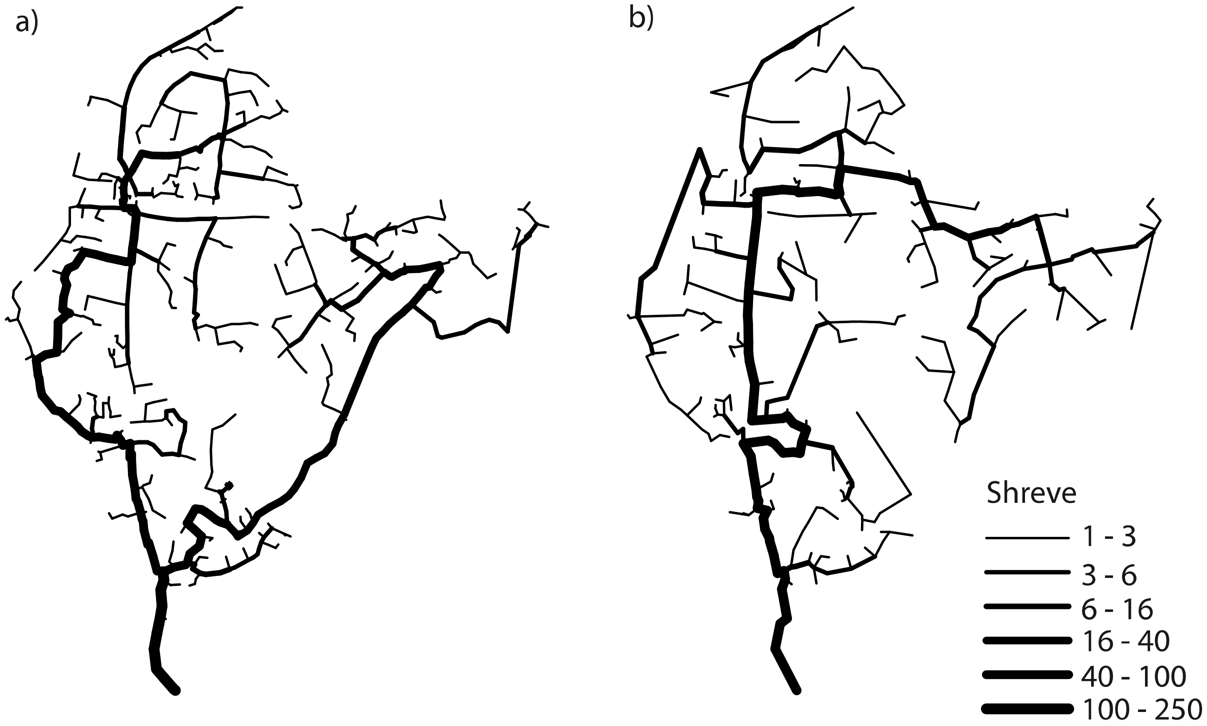




Small segments tend to disappear : Shreve magnitude drops from 131 to 84
Mainforce in the western part of the catchment cannot be accounted for

Results (2/3) : cost function 2

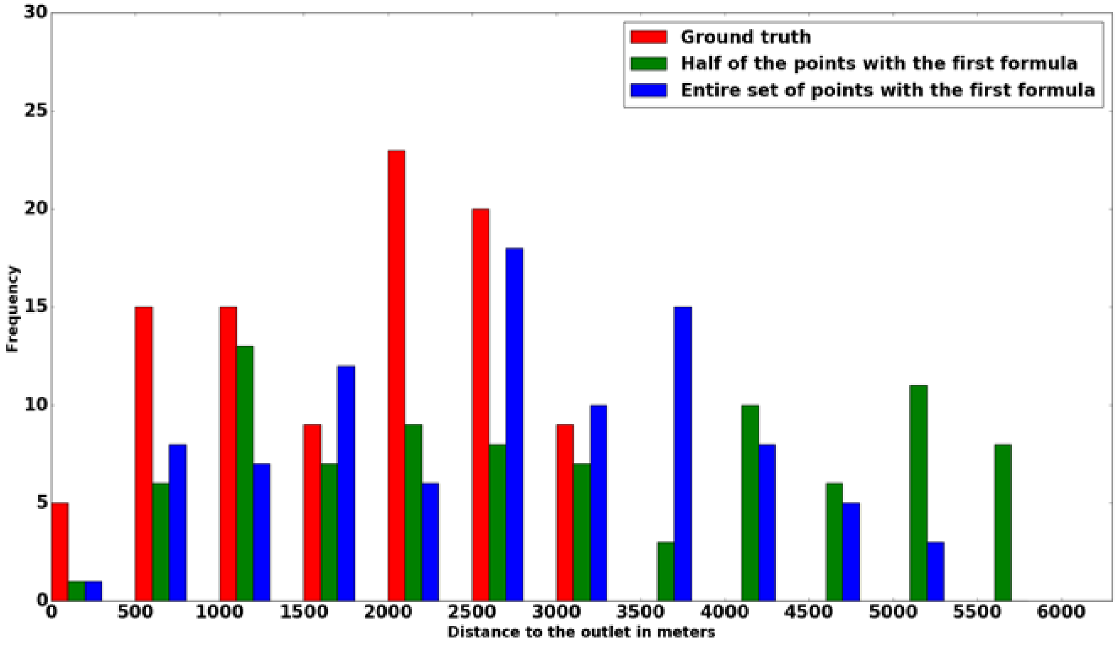
Cost function	Correctness	Completeness	Quality
All nodes	0.90	0.93	0.84
Half of the nodes	0.54	0.66	0.42

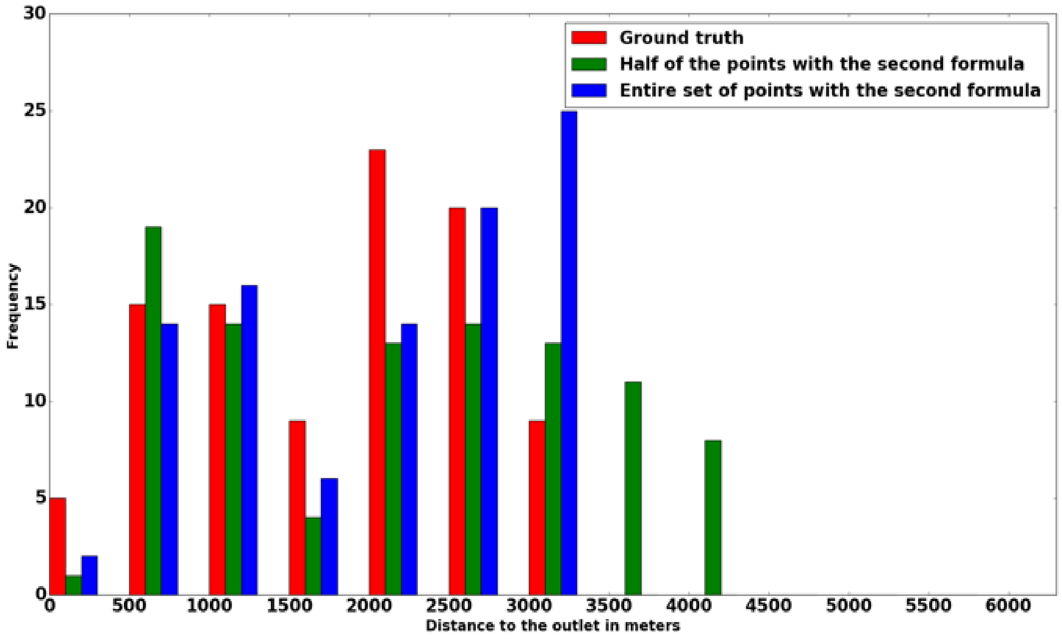


All three criteria have higher values than with cost function 1

Shreve magnitude is 96

Results (3/3) : distance to the outlet





The second cost function yields more realistic results.

Conclusion and perspectives

- Manhole cover location can be used to create wastewater network maps.
  - When using VHR images false positives may be included
  - Stormwater manhole covers may be confused with wastewater ones
- Slope is the least reported variable… and the most sensitive in hydraulic modelling…

- Perspectives
  - Determination of the geometric features of the network ? Can data mining be helpful?
  - What about uncertainty ? Include noise and generate probable network configurations.
  - Does it work elsewhere? Insure genericity by testing on more catchments.

Mapping examples found in the literature for stormwater/wastewater networks

- Optimise network layout using
  - Dynamic programming (Walter, 1995)
  - Linear programming (Swamee and Sharma, 2013)
  - Ant algorithms (Afshar, 2007; Moeini and Afshar, 2012)

- Reproduce the layout of existing networks using node to link information provided by urban databases and operators (Allard et al., 2013 and Blumensaat et al., 2012)