



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

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The context



Sud Oest, 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.

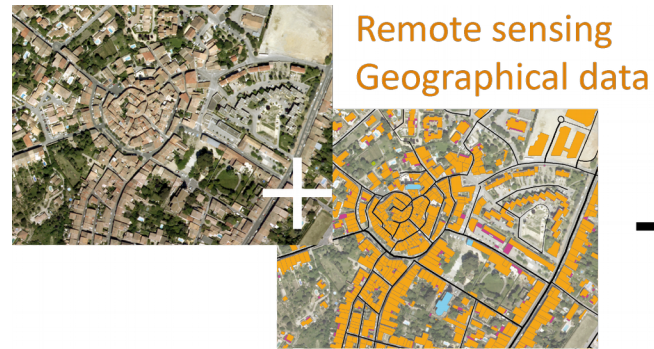


The cable should not have been encased in concrete. It should have been moved in consultation with the electricity distribution company.

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



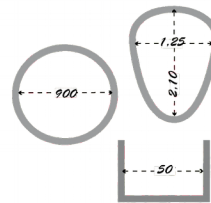
Remote sensing
Geographical data

Schema directeur d'Assainissement
 Le Schéma Directeur d'Assainissement définit, réglemente les types d'assainissement à installer dans la commune. L'article 35 de la loi du 3 janvier 1992 impose à chaque commune de se doter d'un Schéma Directeur d'Assainissement au plus tard le 31 décembre 2012.

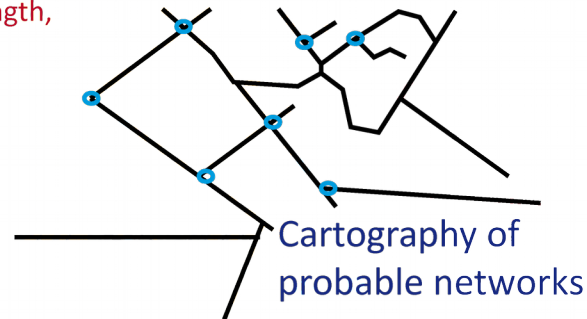
PREC_ALT	NATURE	NUMERO	BOM_VOIE_G
1	Escalier	NC	ALL DES 4 CANTONS
1	Sentier	NC	ALL JEAN DE BERG
1	Sentier	NC	ALL DU SOLEIL COUCHANT
1	Sentier	NC	CHE DE LA PASSERELLE
1	Sentier	NC	CHE DU STADE
2.5	Sentier	NC	R DE POINTE VERTUE
2.5	Ruelle à 1 chaussée	NC	CHE DU PONT VIEUX
2.5	Escalier	NC	ALL DES TABARNS
2.5	Passe piétons	NC	CHE DE LA MAIRIE VOIE FERREE
2.5	Sentier	NC	R DES PASSERELLES
2.5	Sentier	NC	CHE DE LOU DU BITOULET
2.5	Sentier	NC	PAS DU SALARRE
9999	Sentier	NC	AV HENRI FRENEL
2.5	Sentier	NC	ALL DES TABARNS
1	Ruelle à 1 chaussée	NC	R JUSTIN SABLER
1	Sentier	NC	R BRON
1	Sentier	NC	R DE LA MARQUISE
1	Sentier	NC	R BARBAROUS
2.5	Chemin	NC	R DES CONSCRBS
9999	Sentier	NC	PAS DE HERMES
9999	Sentier	NC	ALL DU TOURSME
1	Sentier	NC	BP DU PORCHE
1	Escalier	NC	R DU PUIS
1	Escalier	NC	PAS HURELLE
1	Escalier	NC	PAS DE LA VILLE

Data mining

Attributes:
Position, material, length,
Diameter, dates...

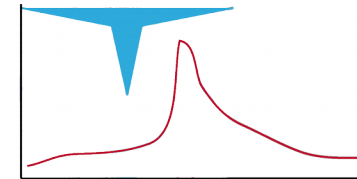


Text analysis



Cartography of probable networks

Hydraulic modelling



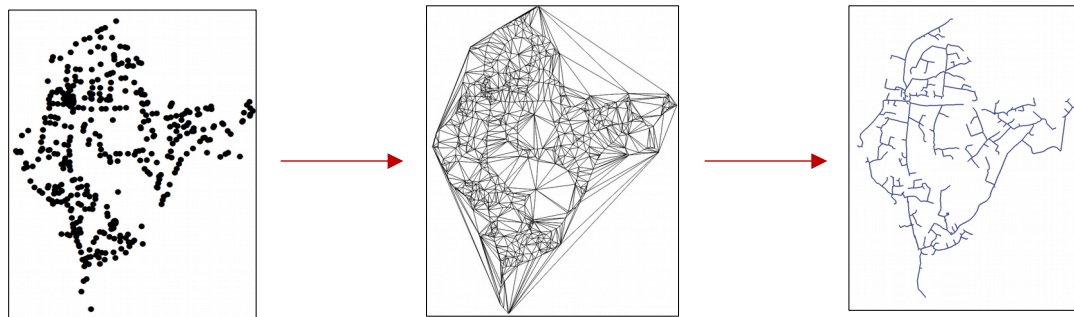
- Can an existing network be mapped based on manhole cover locations ?
- Optimal configuration may be determined (Walter, 1995; Afshar, 2007; Swamee & Sharma, 2013; Moeni and Afshar, 2012)
- Existing network layout may be reproduced if node to link or PE data is available (Allard et al., 2013; Blumensaat 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., 2016; Commandré et al., 2017).



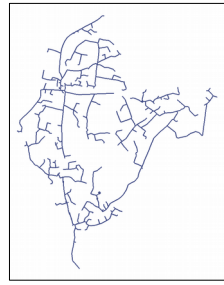
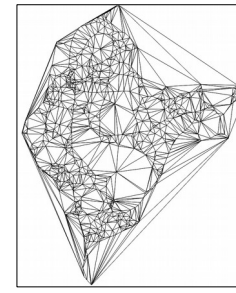
- Step 1: Compute a Delaunay triangulation based on the set S .
 - Assign $c(P_iP_j)$ i.e the “cost” for wastewater to flow from P_i to P_j . $c(P_iP_j) = -c(P_jP_i)$
- Step 2: Extract the Minimum Spanning Tree using Kruskal’s algorithm (1956).



The methodology (2/2)

■ Two examples of cost functions

⚠ Assume surface and underground slopes to be parallel ⚠



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

l_{ij} : length of edge $P_i P_j$

[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

$$■ c_2(P_i P_j) = \alpha \frac{\text{rank}(l_{ij})}{\max(\text{rank}(l_{ij}))} + (1 - \alpha) \delta \frac{\text{rank}(|S_{ij} - S_m|)}{\max(\text{rank}(S_{ij} - S_m))} + \beta + \gamma S_{ij}$$

S_{ij} : slope of edge $P_i P_j$

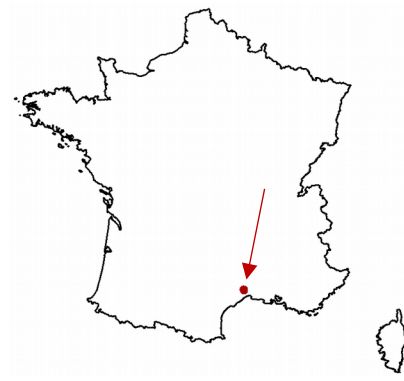
[L.L⁻¹];

S_m : mean value of the interval [2 ‰, 7 ‰]

[L.L⁻¹]

$\delta = 0$ if the slope is in the interval, otherwise $\delta = 1$

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

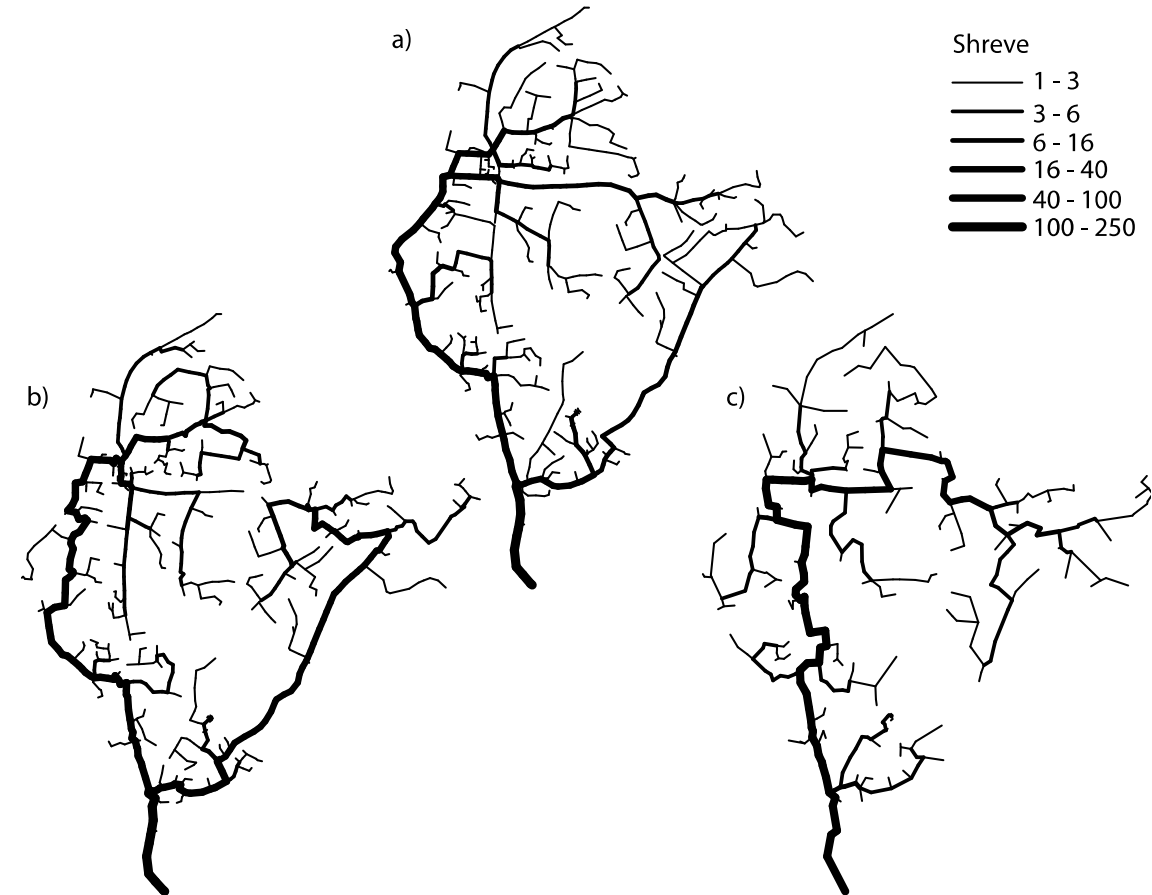
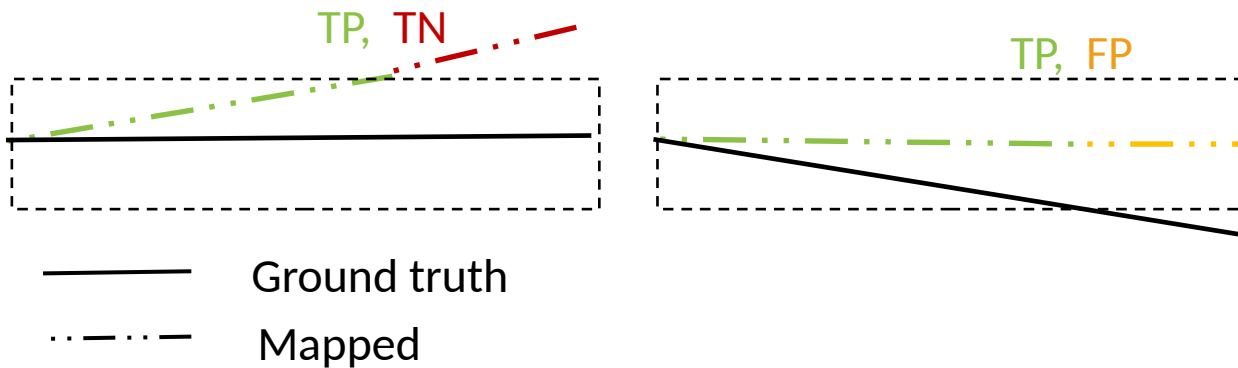


- 799 manhole covers and 23.45km of pipes (operator data).
- Geographical data base (DEM, roads, buildings) available through IGN.
- Randomly select $\frac{1}{2}$ of manhole covers to test the algorithm
- Assess and compare
 - Correctness, completeness, quality (Heipke et al., 1997).
 - Network hierarchy (Shreve, 1966).
 - Distance to the outlet (Allard et al.2013).



Results (1/3) : cost function 1

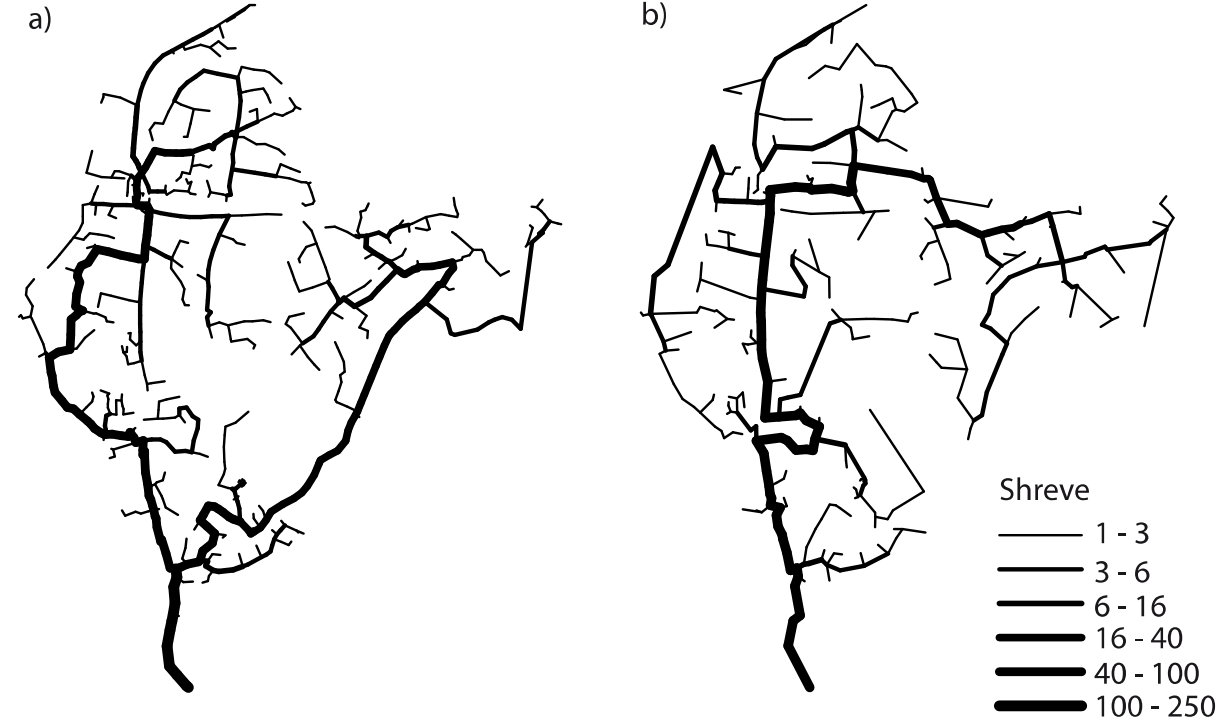
Cost function	Correctness	Completeness	Quality
All nodes	0.89	0.84	0.76
Half of the nodes	0.44	0.55	0.32



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

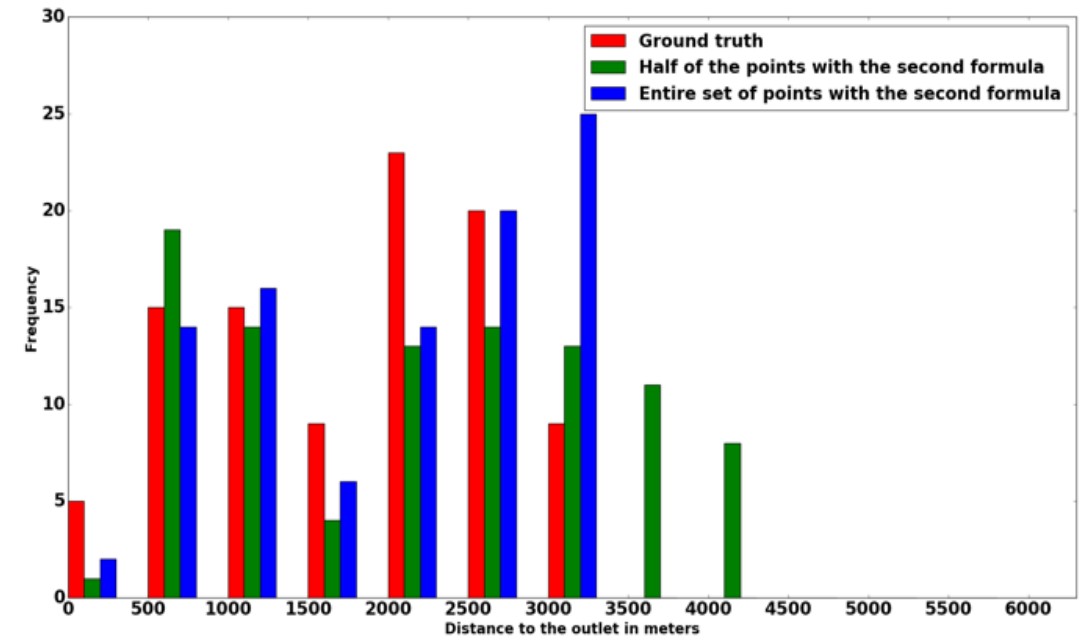
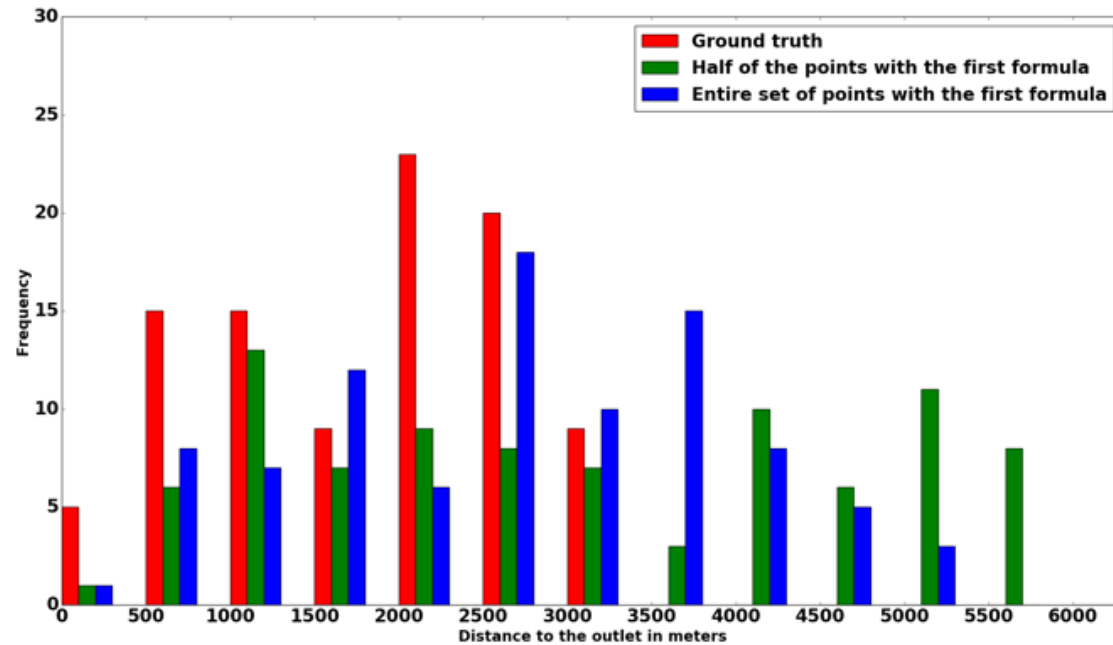
Results (2/3) : cost function 2

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)