

Crowdsourcing ground-truth datasets for building change detection

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Session S1: Urban Complexity 1



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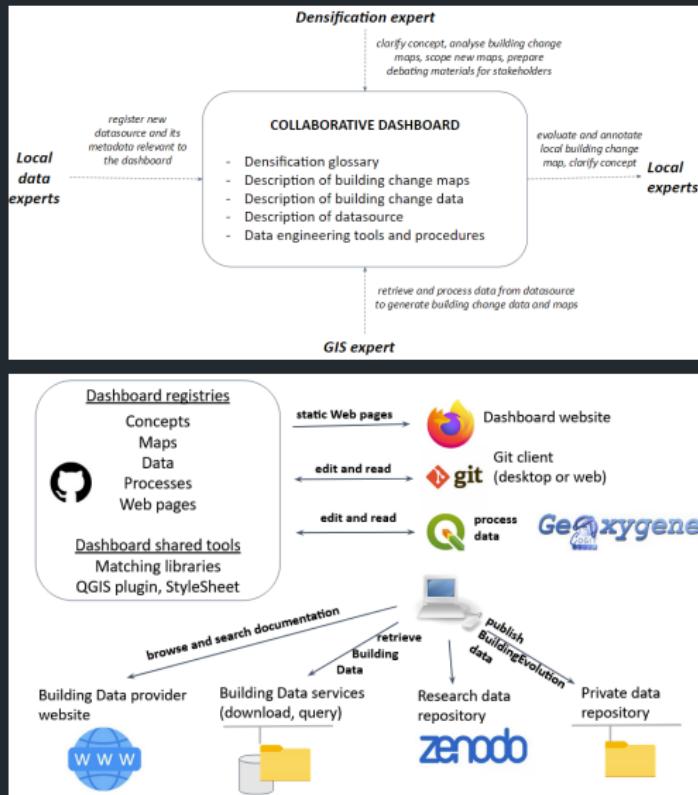
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- Understand urban densification dynamics for sustainable planning [Batty, 2018], with an integrated assessment of trade-offs between Sustainable Development Goals [Raimbault and Pumain, 2022] (linked to densification: increased access and limited sprawl vs UHI and less green space [Evers et al., 2024]).
- In the suburban case, processes at multiple scales with diverse stakeholders; difficult to control through policy [Jehling et al., 2020]; the SUBDENSE European project to understand qualitatively and quantitatively these polyrationalities.
- Need for a consistent, despite various GIS data qualities across compared countries (FR, UK, DE), quantification of urban change **at the building scale**.

A collaborative dashboard for mediation

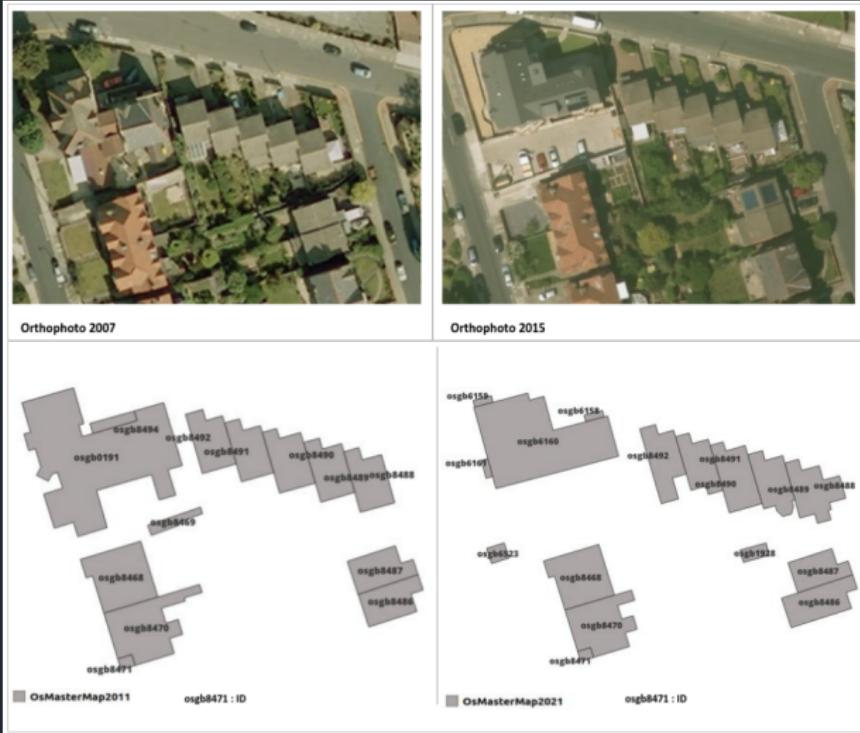


Preliminary work aimed at harmonising operational concepts and data sources qualification across the different countries:

→ git-based dashboard to share knowledge and resources between different types of experts [Bucher et al., 2024]

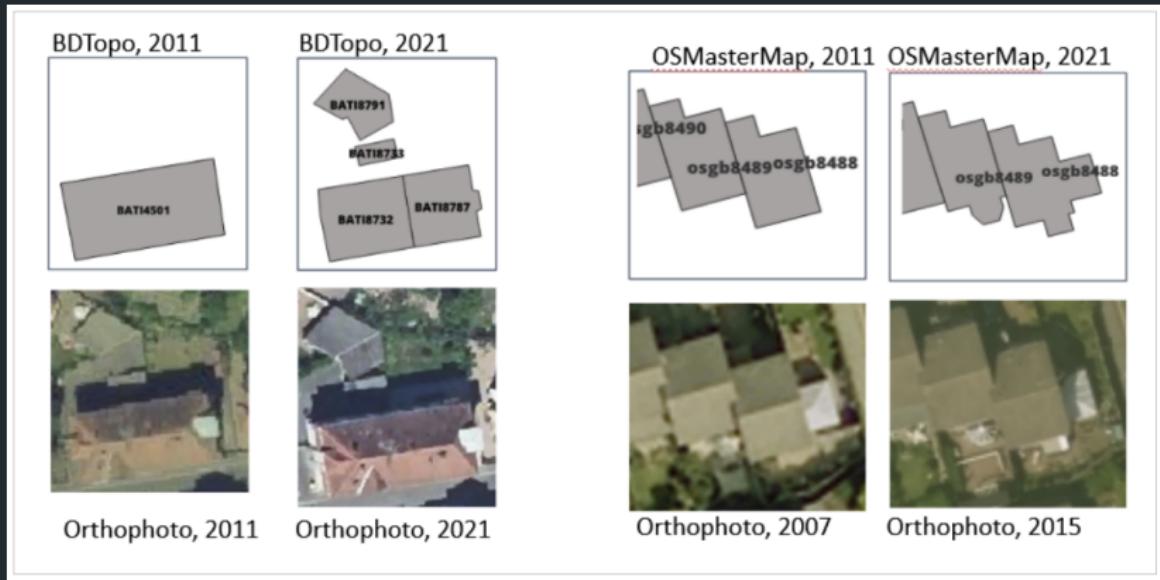
→ reproducible tools and methods, including **building change detection scripts**

Difficulties with data for building change



Example in the UK where changes in OS MasterMap building data includes both real changes and data changes. Source: [Bucher et al., 2025]

Difficulties with data for building change



Example of data specification changes only, for France (BDTopo) and the UK (OSMasterMap). Source: [Bucher et al., 2025]

- Machine Learning on remote sensing raster data had improved performance in recent years, but remains not robust enough in terms of quality and resolution for that particular purpose
[Khelifi and Mignotte, 2020]
- Geospatial vector data matching algorithms as a method for change detection [Xavier et al., 2016], applied to linear data [Costes et al., 2015] and polygonal data [Gregory and Healey, 2007].
- A new algorithm combining Geometric Matching of Areas [Bel Hadj Ali, 2001] with Multi-criteria Matching [Olteanu-Raimond et al., 2015] presented at CCS last year [Guardiola et al., 2024b].

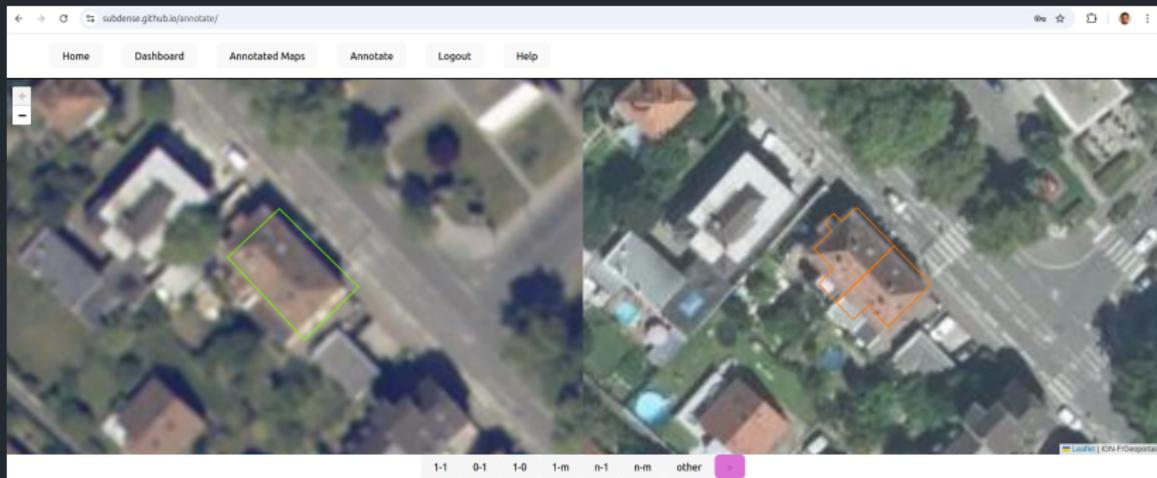
- Vector Matching algorithm require extensive parametrisation and optimisation, and provide varying performances in different context.
- Need for large and specific ground-truth datasets (building layers annotated with expected links).

Research objective:

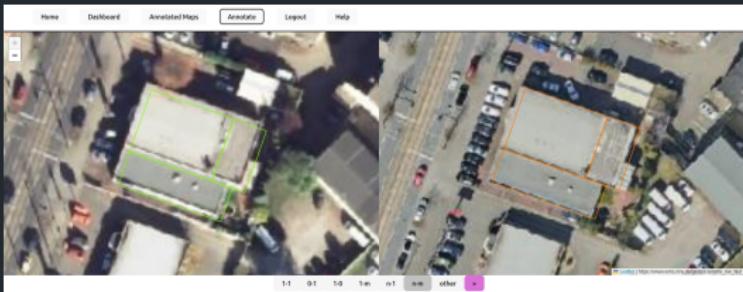
Design and develop a web application designed to annotate potential matching links between two vector dataset.

Functionalities of the annotation web-application

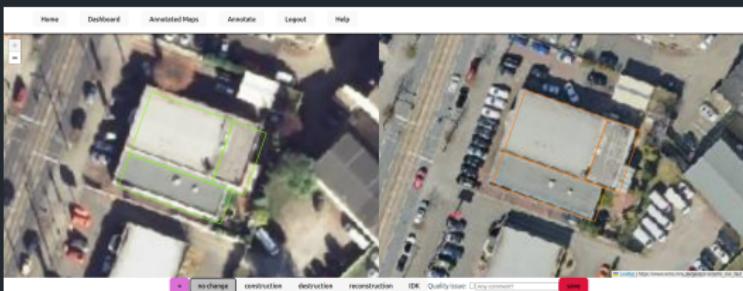
- fully based on git and javascript: no database nor server management, automatically deployed through github pages
- handles multi-user collaboration, with authentication given by writing rights on the git repository
- provides a dashboard to summarise user progress and overall progress
- allows annotation of two vector datasets, with aerial photographs being provided in the background for ground-truthing



Two stage annotation process

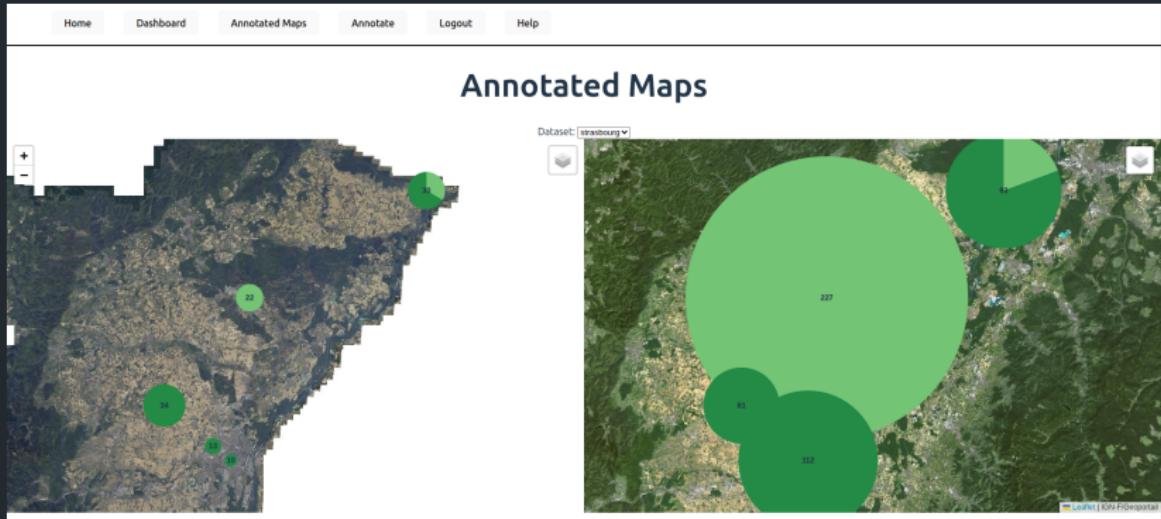


Stage 1: type of matching link (1-1, 0-1, 1-0, 1-m, n-1, n-m).



Stage 1: type of real word evolution (no change, construction, destruction, reconstruction, don't know), signal a quality issue and comment.

Dashboard and maps to monitor progress



Deployment

Work in progress: algorithm optimisation

-  Batty, M. (2018).
Inventing future cities.
MIT press.
-  Bel Hadj Ali, A. (2001).
Qualité géométrique des entités géographiques surfaciques. Application à l'appariement et définition d'une typologie des écarts géométriques.
Theses, université Gustave Eiffel ; Anciennement Université de Marne La vallée.

-  Bucher, B., Brasebin, M., Buard, E., Grosso, E., Mustière, S., and Perret, J. (2012).

Geoxygene: Built on top of the expertise of the french nma to host and share advanced gi science research results.

In *Geospatial Free and Open Source Software in the 21st Century: Proceedings of the first Open Source Geospatial Research Symposium, OGRS 2009*, pages 21–33. Springer.

-  Bucher, B., Ndim, M., Olteanu-Raimond, A.-M., Rimbault, J., Perret, J., Dembski, S., and Jehling, M. (2024).
Conceptualising a co-operative building evolution dashboard on city regions over the past decades for densification studies.
In *27th AGILE Conference on Geographic Information Science, "Geographic Information Science for a Sustainable Future"*, volume 5.

-  Bucher, B., Raimbault, J., Ndim, M., Raimond, A.-M., Perret, J., Dembski, S., and Jehling, M. (2025).
A building changes model to support comparative studies and open discussions on densification.
Under review for IJGI.
-  Costes, B., Perret, J., Bucher, B., and Gribaudo, M. (2015).
An aggregated graph to qualify historical spatial networks using temporal patterns detection.
In *The 18th AGILE International Conference on Geographic Information Science*.

-  Evers, D., Katurić, I., and van der Wouden, R. (2024). *Urbanization in Europe: Past Developments and Pathways to a Sustainable Future.* Springer Nature.
-  Gregory, I. N. and Healey, R. G. (2007). **Historical gis: structuring, mapping and analysing geographies of the past.** *Progress in human geography*, 31(5):638–653.

-  Guardiola, P., Rimbault, J., Olteanu-Raimond, A.-M., and Perret, J. (2024a).
Benchmarking algorithms for matching geospatial vector data.
In *Proceedings of the French Regional Conference on Complex Systems*, pages 277–280.
-  Guardiola, P., Rimbault, J., Olteanu-Raimond, A.-M., and Perret, J. (2024b).
Optimising geospatial vector data matching algorithms for change detection with synthetic data.
In *Conference on Complex Systems 2024*.

-  Harvey, F., Vauglin, F., and Bel Hadj Ali, A. (1998).
Geometric matching of areas, comparison measures and association links.
In *Proceedings of the 8th International Symposium On Spatial Data Handling*, pages 557–568.
-  Jehling, M., Schorcht, M., and Hartmann, T. (2020).
Densification in suburban germany: approaching policy and space through concepts of justice.
Town Planning Review, 91(3):217–237.

-  Khelifi, L. and Mignotte, M. (2020).
Deep learning for change detection in remote sensing images: Comprehensive review and meta-analysis.
IEEE Access, 8:126385–126400.
-  Mustière, S. (2002).
Description des processus d'appariement mise en oeuvre au cogit, rapport 2002.0072, chap.6.
Technical report, IGN.
-  Olteanu-Raimond, A.-M., Mustiere, S., and Ruas, A. (2015).
Knowledge formalization for vector data matching using belief theory.
Journal of Spatial Information Science, (10):21–46.

-  Rimbault, J. and Pumain, D. (2022).
Trade-offs between sustainable development goals in systems of cities.
Journal of Urban Management, 11(2):237–245.
-  Xavier, E. M., Ariza-López, F. J., and Urena-Camara, M. A. (2016).
A survey of measures and methods for matching geospatial vector datasets.
ACM Computing Surveys (CSUR), 49(2):1–34.

Reserve slides

The SUBDENSE project

The SubDense European project studies the dynamics of suburban densification by:



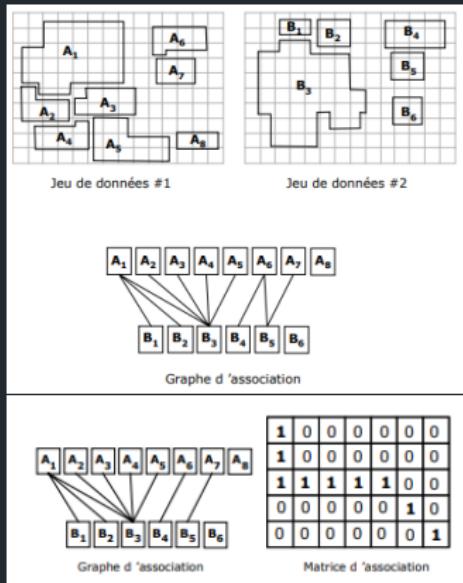
Understanding polyrationalities
of space, actors and policies
on suburban densification

- exploring how diverse strategies of land policy interact with landowners' and local stakeholders' interest and agency to shape suburban densification and their impact on suburbia across different planning systems (France, Germany, UK);
- combining quantitative approaches (geodata analysis and geosimulation) with qualitative approaches (social and policy science and planning).

Geometric Matching of Areas (GMoA) algorithm

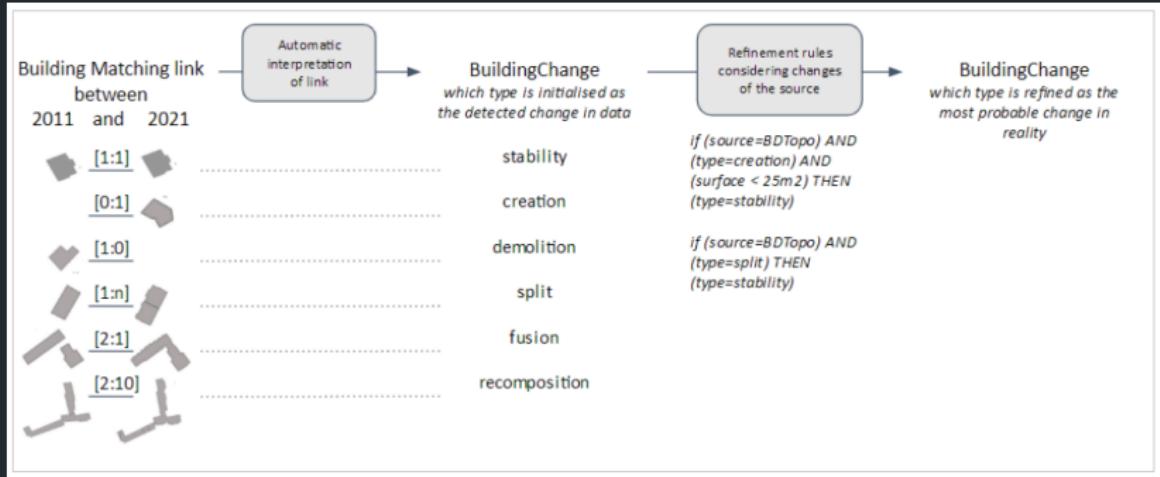
Algorithm to produce m-n links based only on geometries [Harvey et al., 1998]
[Bel Hadj Ali, 2001]:

1. Construct all possible association links as surfaces with a non-empty intersection (top left Fig.)
2. Filter links with an intersection surface below a threshold parameter
3. Filter links with an intersection surface too small relatively to matched surfaces (rate parameter)
4. Construct all m-n links as connected clusters in the remaining bipartite graph (bottom left Fig.)



→ implemented in the geoxygene java library [Bucher et al., 2012] by [Mustière, 2002]

Application of the GMoA to change detection



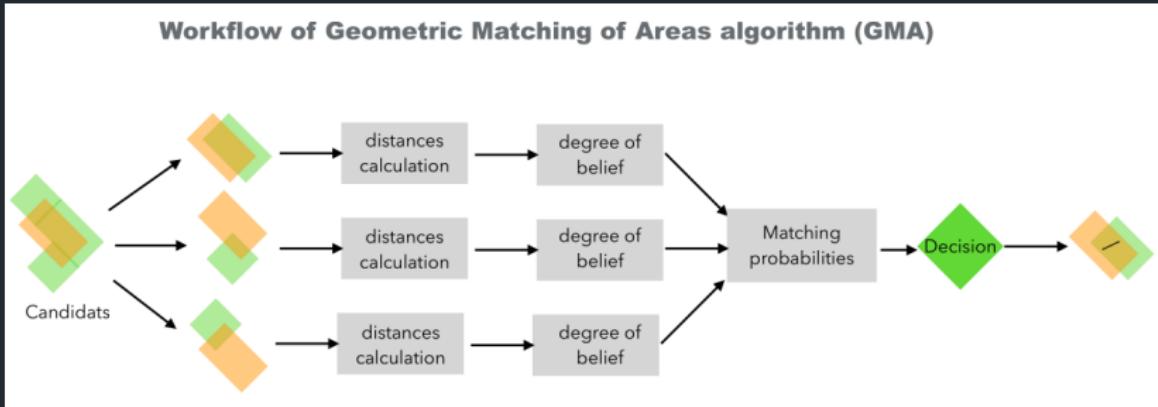
Automatic interpretation of matching links into building change, with specific adjustments for BDTopo [Bucher et al., 2025], by a python script available at
<https://github.com/subdense/matching>

Example



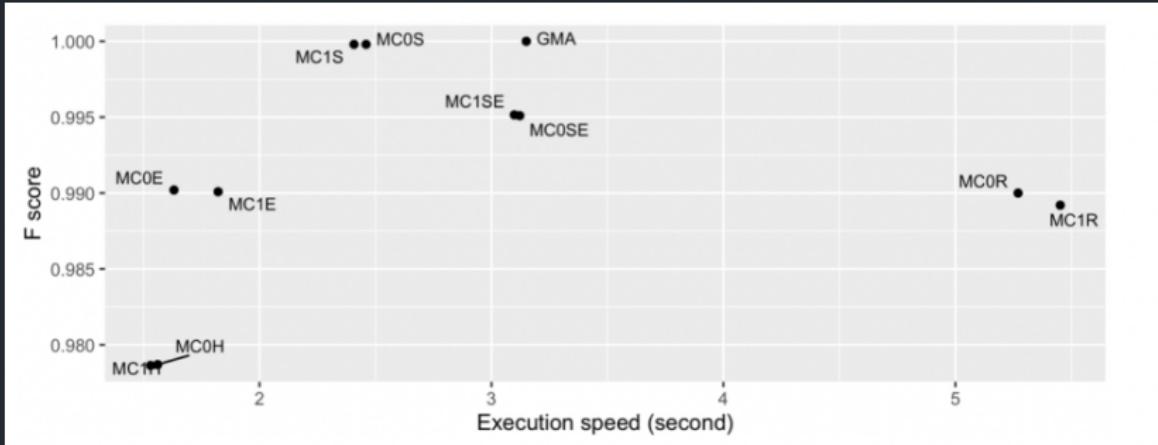
Building evolution for two examples in the urban area of Strasbourg
[Bucher et al., 2025]

Multi-criteria matching algorithm (MCA)



Implementation of the Multi-criteria matching algorithm
[Olteanu-Raimond et al., 2015] in python by
[Guardiola et al., 2024a], with euclidian, surface, radial and
Hausdorff distances, and run twice to obtain m-n links.

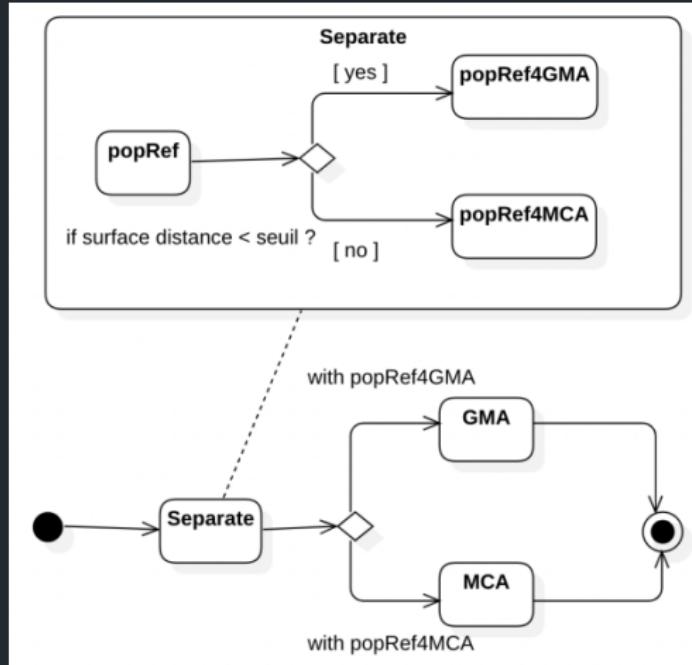
Benchmarking of algorithms



Bi-objective benchmark optimising for performance (F-score on a $\simeq 2k$ buildings ground truth dataset) and runtime, for different parametrisations of the two algorithms, by [Guardiola et al., 2024a]

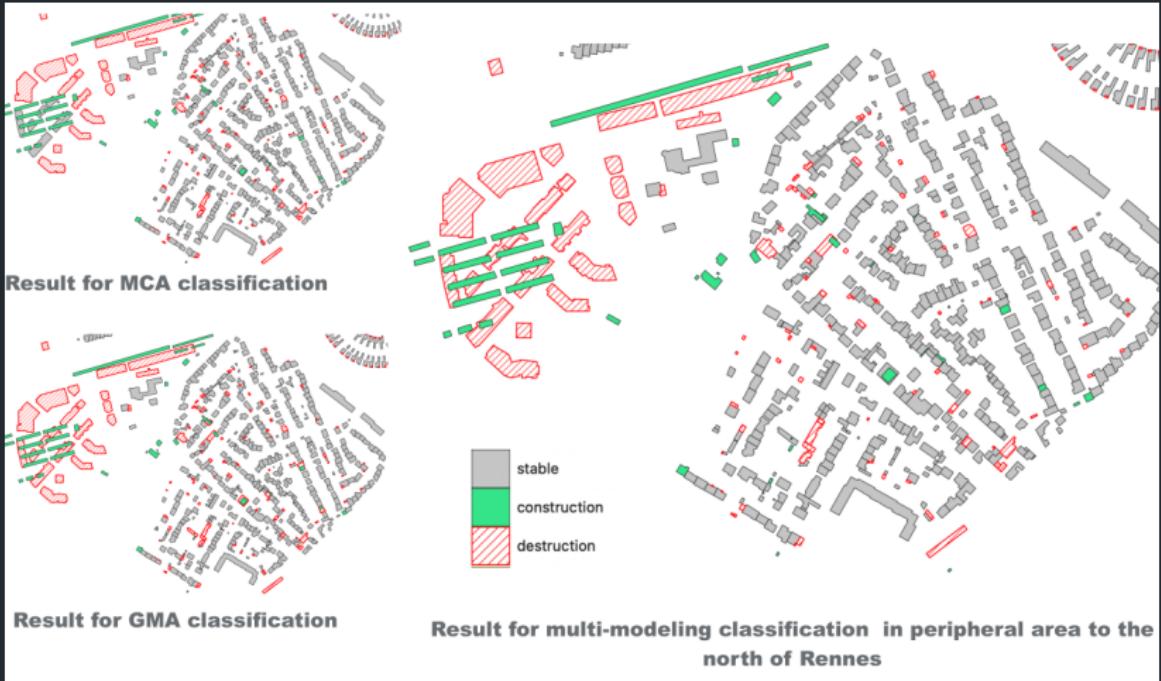
- various algorithm performances
- under-detection of change by GMoA and over-detection by MCA
- GMA better for m-n links, MCA better for 1-1 links

A new algorithm using multi-modeling



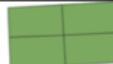
Proposition of a new algorithm combining GMoA and MCA, with the choice made through thresholding surface distance [Guardiola et al., 2024b]

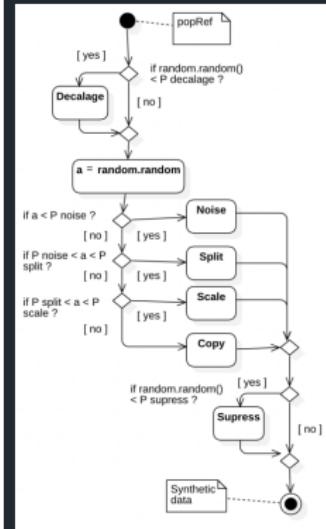
Example



Results obtained on an example in the suburbs of Rennes
[Guardiola et al., 2024b]

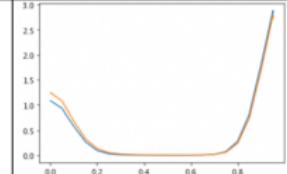
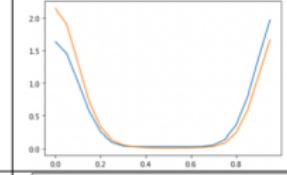
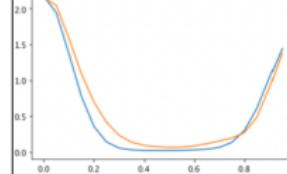
Validating the algorithm with synthetic data

	popRef	popCreate
Decalage		
Noise		
Split		
Scale		
Copy		
Suppress		



Synthetic data generator introduced by [Guardiola et al., 2024b] to generate datasets on which to validate and optimise the algorithm

First results on synthetic data

Lieu Géographique	Valeur des paramètres optimisés	Courbes des densité des distances surfacique de popRef et popCreee
Centre Urbain	Decallage = 0.05 Brouilleur = 0.45 Echelle = 0.20 Spliteur = 0.25 Copieur = 0.10 Suppression = 0.10	
Banlieue	Decallage = 0.10 Brouilleur = 0.75 Echelle = 0.10 Spliteur = 0.05 Copieur = 0.10 Suppression = 0.10	
Ville périphérique	Decallage = 0.10 Brouilleur = 0.25 Echelle = 0.40 Spliteur = 0.15 Copieur = 0.15 Suppression = 0.10	

Integration into the OpenMOLE software and calibration of the generator for different urban typologies (single fitness: distance between surface distance densities) [Guardiola et al., 2024b]