

Quantifying the co-evolution of economic activities locations with geo-historical data: Paris, 19th century

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Social Dynamics in Urban Context

Open tools, models and data - Paris and its suburbs, 1789-1950

Welcome to the SODUCO project

SODUCO is a 4 years pluridisciplinary project funded by the French National Research Agency, it has started in march 2019 and will end in 2023. SODUCO brings together people from the geographical sciences, from urban history, specialists of network morphogenesis and computer scientists to study the evolution of Paris over time, both in terms of its morphological transformations and its social evolutions.

Project partner institutions

L'ÉCOLE
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SCIENCES
SOCIALES

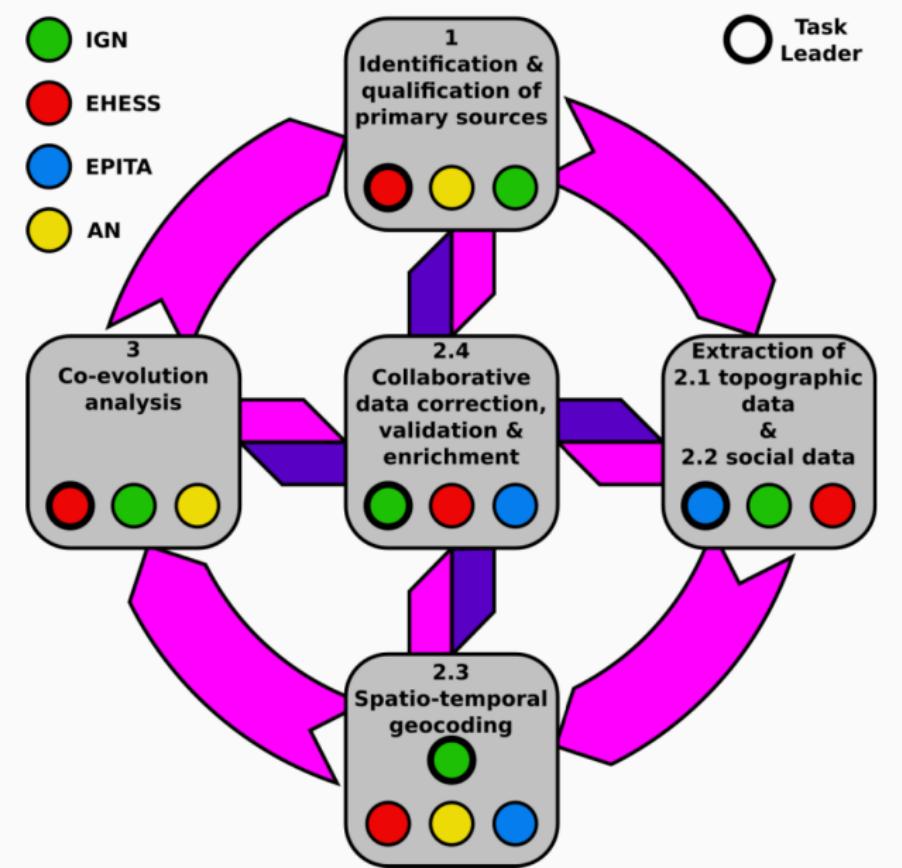
IGN
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<https://soduco.github.io/>

Structure of the SODUCO project



WP 1: Identification and qualification of relevant sources

→ Catalog of primary sources; qualification of sources and metadata construction; online publication as Linked Open Data; modeling of uncertainties.

WP 2: Digitalisation of sources

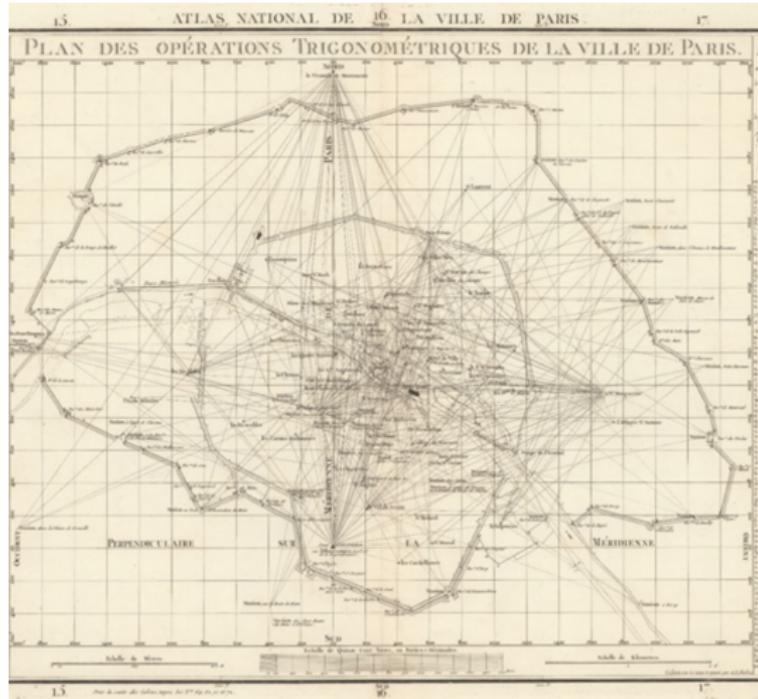
→ Extraction of topographic data (2.1); extraction of socio-economic data (2.2); spatio-temporal geocoding (2.3); collaborative data correction, validation and enrichment (2.4).

WP 3: Co-evolution analysis

→ geovisualisation of data and associated dynamics.

Tools: collaborative open platform to ensure reproducibility and traceability of data and processes.

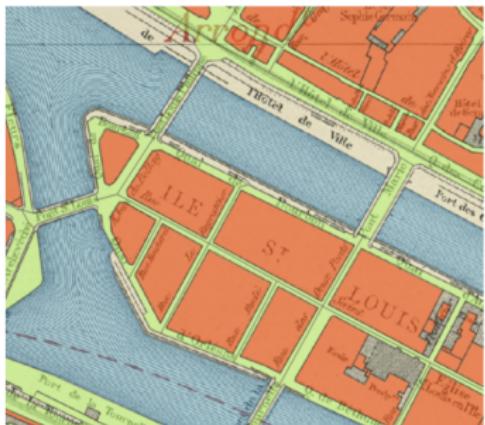
Verniquet atlas accuracy



Fieldwork survey with modern instruments to verify the planimetric accuracy of Verniquet atlas (claimed at 1/10 of a toise $\simeq 19\text{cm}$)

- Claimed uncertainties were correct
- CRS parameters for the historical coordinate system (reused as reference in many historical plans)

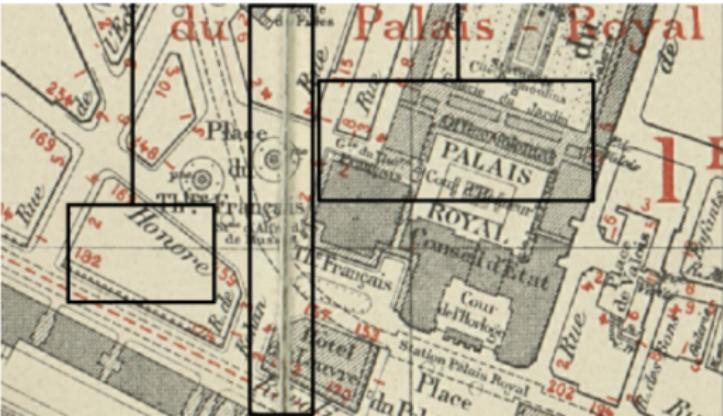
Vectorisation of historical maps



Historical Map



Deep Contour Detection



Edge Probability Map



Filtering & Watershed



Closed Shapes

PhD thesis by Yizi Chen soon finished: vectorisation combining deep learning and mathematical morphology [Chen et al., 2021b] [Chen et al., 2021a]

- Multi-dimensionality of urban systems is one aspect of their complexity, strongly present in the co-evolution of economic activities locations.
- Understanding past processes better inform urban theories and models for future sustainable planning.

Research objective of this contribution (partly WP3):

Use geo-historical data to quantify the co-evolution of economic activities in Paris during the 19th century; methodological aspects on the issues linked to the exploitation of such data.

Urban systems and geo-historical data

- Contemporary intra-urban dynamics are better and better characterised through the emergence of urban data and urban analytics [Kandt and Batty, 2021]; more difficult with past dynamics.
- Interdisciplinary approaches to the modeling of settlement systems transitions: qualitative or very sparse data, stylised models (Transmondyn project) [Sanders, 2018]
- Stylised models for systems of cities on long time scales [Pumain and Reuillon, 2017]
- Difficulty to build geo-historical data: geocoding [Cura et al., 2018], vectorisation [El Gouj et al., 2022]

Data extraction

Several commercial economic activities repertoires, archived and digitalised.



→ Work on *Didot-Bottin*, covering most of 19th century (to avoid multi-source bias for now)

→ Document segmentation, OCR

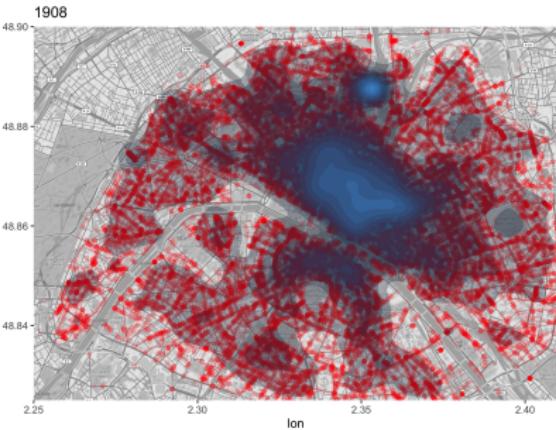
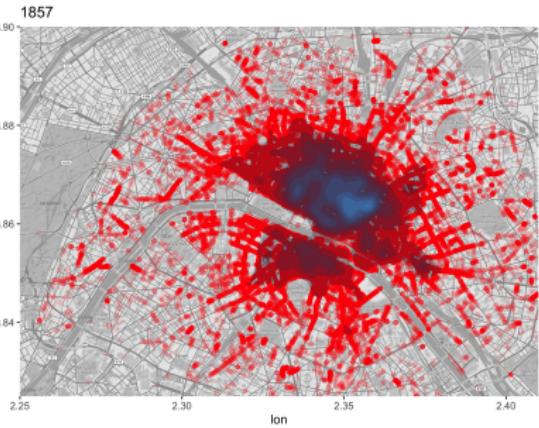
→ Named Entity Recognition to extract names, addresses, activities

→ Historical geocoding

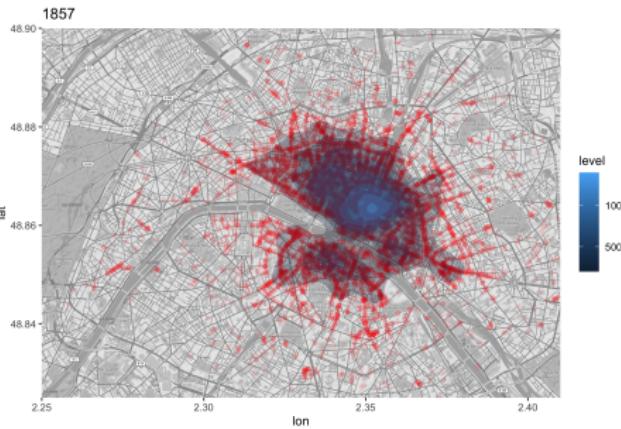
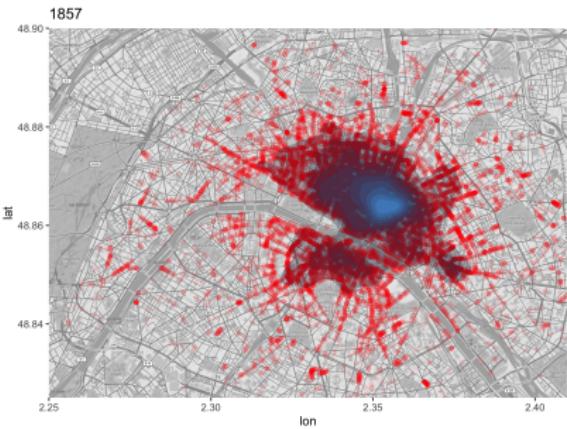
Data pre-processing

- Data covering 1857-1908: 4,218,048 entries, 80.32% with coordinates and a defined activity.
- Natural Language Processing: stop-words removal and stemming to descriptions of activities.
- Stems with more than 100 occurrences (996) coded for broad activities (food, craftsmanship, art and literature, health, law and governance, service, teaching)
- 1,990,222 entries with coordinates and classified activities

Location of activities



Location of activities



Left: craftsmanship; Right: food.

Defining co-evolution

Objects: Cities and territories (*Evolutionary Urban Theory* [Pumain, 2018]) co-evolving with transport networks (*Territorial Theory of Networks* [Dupuy, 1987])

Processes:

A multi-level definition of co-evolution:

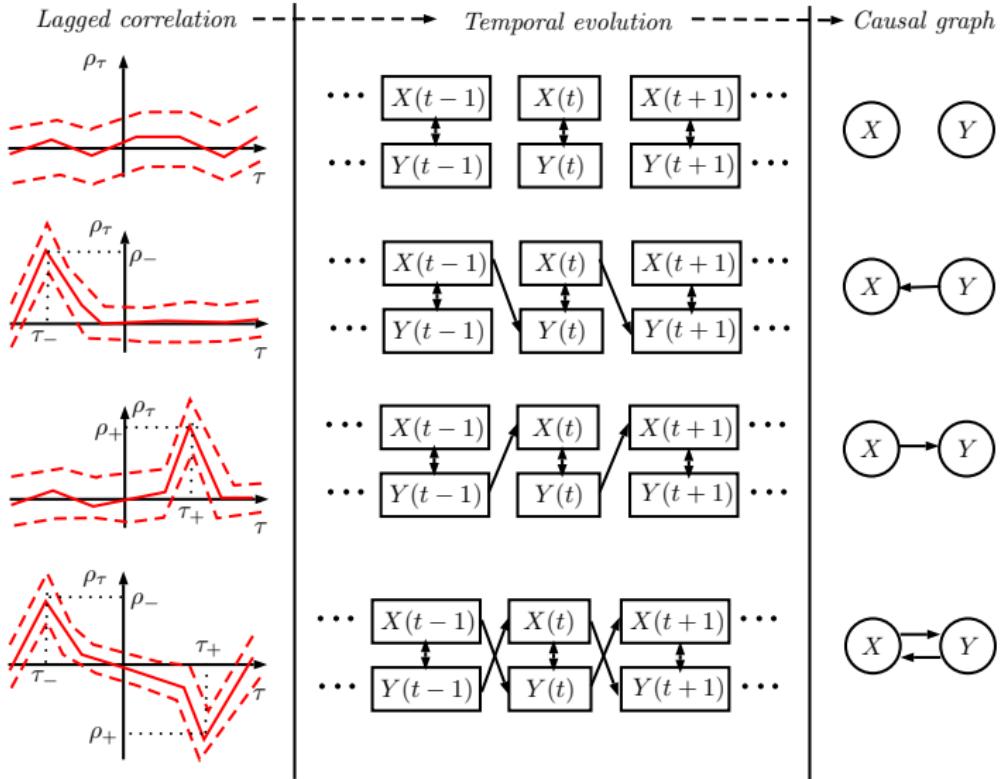
- ① agents level
- ② agent populations level (niches)
- ③ global system level

Corresponding approaches:

- ① Empirical approach (microscopic level)
- ② Morphogenesis approach (niche level)
- ③ Evolutionary theory approach (global level)

Raimbault, J. (2019). Modeling interactions between transportation networks and territories: a co-evolution approach. arXiv preprint arXiv:1902.04802.

Method to characterise co-evolution

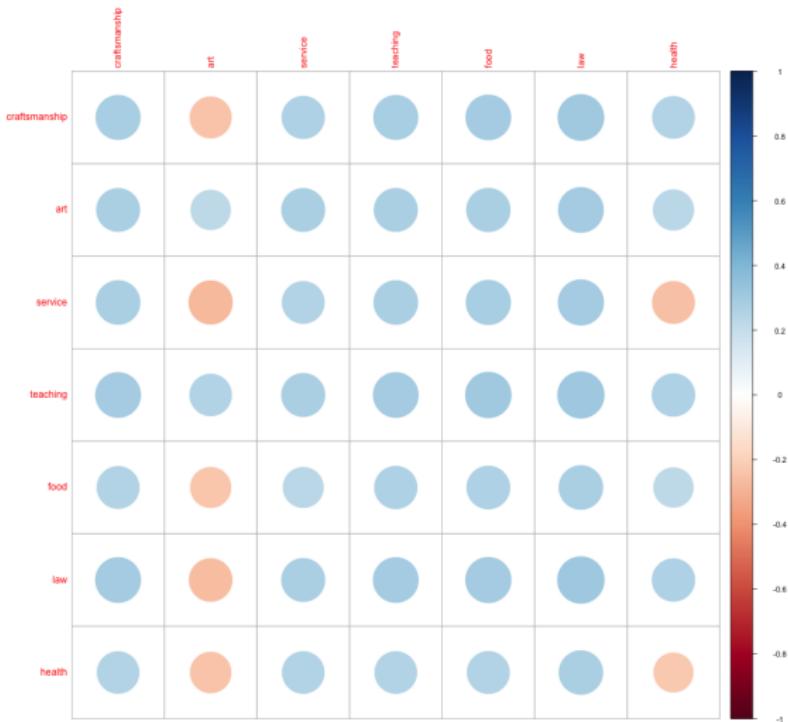


Application to this dataset

- Activity counts $N_{a,r}$ within raster cells: 10x10 grid to split the covered area into zones.
- Variation of activity counts in time $\Delta N_{a,r}(t) = N_{a,r}(t + \Delta t) - N_{a,r}(t)$
- Lagged correlations in time between activities

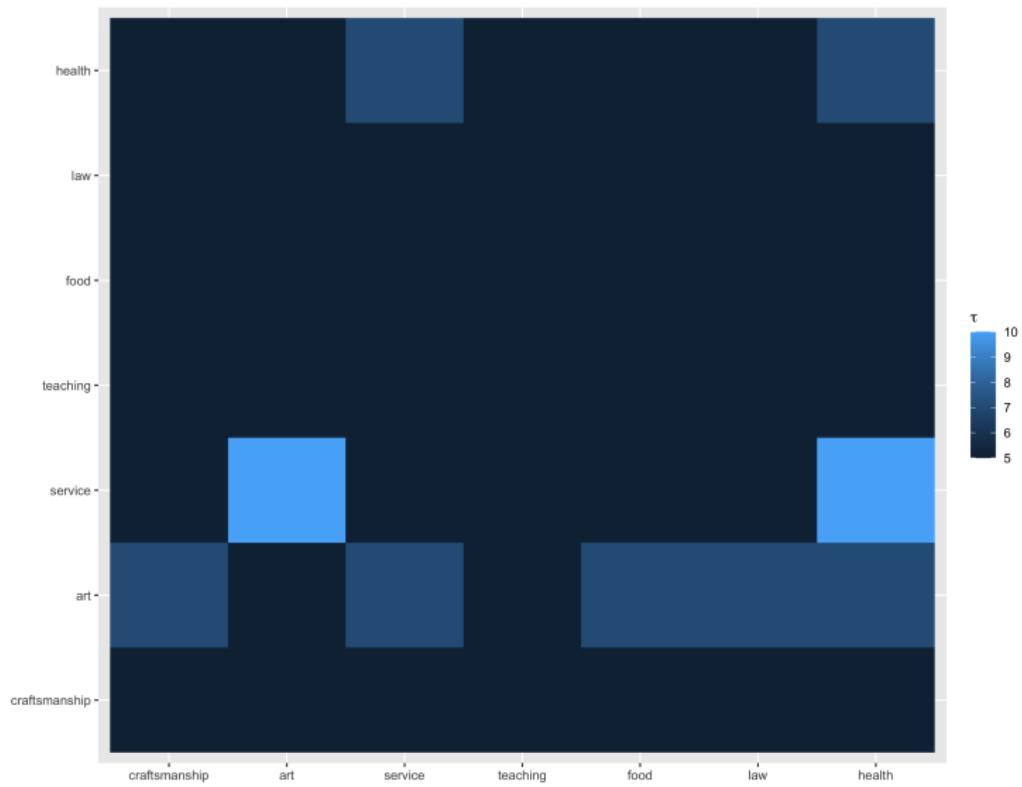
$$\rho_{a_1,a_2}(\tau) = \rho [\Delta N_{a_1,r}(t), \Delta N_{a_2,r}(t - \tau)]$$

Results: lagged correlations



Optimal lagged correlations between variations of activity counts

Results



Corresponding delays

- Micro insights into historical intra-urban economic processes.
- Existence of a co-evolution between some activities (circular causality in location dynamics).
- In discussion with historians in the project: capture qualitative knowledge (e.g. "*fabrique urbaine*")?

Current and future work:

- Sensitivity analysis to classification, meta-parameters; null model with random activities.
- Endogenous spatial neighbourhoods to estimate correlations, using a GWR-like approach [Brunsdon et al., 1998]; temporal moving-window.
- Benchmark of methods to measure co-evolution (instrumental variables, causal machine learning).

Conclusion

- Geo-historical data is new data; quantification of past intra-urban processes; many consistency and processing issues.
- Opening for interdisciplinary discussions and collaborations: actual new knowledge and its validation depends on disciplines.

Soduco website and repository:

<https://soduco.github.io/>

<https://github.com/soduco>

Models and results open at

<https://github.com/JusteRaimbault/HistoricalData>

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