

A scientometric analysis of linkages between urban digital twins and urban simulation models

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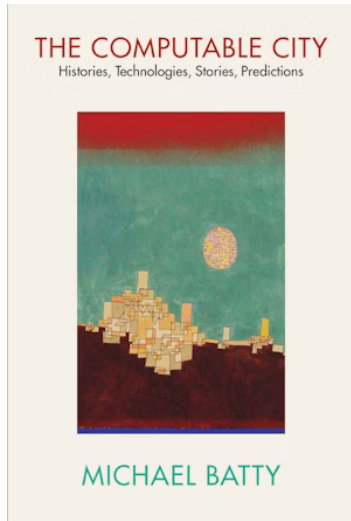
Urban Digital Twins (broad sense of coupled physical system and virtual representation) proposed as a tool for sustainable smart cities with urban planning, design and management impacts in various fields.

Adoption in practice: still mostly prototypes, linked to funding availability, models of socio-technical systems at short time scales (ex. urban climate, buildings, roads, energy, mobility and transport infrastructure, . . .) [Ferré-Bigorra et al., 2022]

Challenges for urban digital twins: interoperability and semantics, infrastructure, data acquisition and actuation, data quality and data fusion, planning and prediction, visualization / information display, Resources, ethical/legal/social aspects [Weil et al., 2023]

Long history in urban simulation models:

- Urban growth and cellular automata
- Agent-based models
- Microsimulation
- Land-use transport interaction models
- Urban mobility
- Environmental sciences: Urban Heat Island, pollution, ...
- ...



[Batty, 2024]

→ digital twins as a trend similar to smart cities, hype or solid ground for future sustainable cities?

→ urban simulation models to understand urban dynamics on several timescales, including long time.

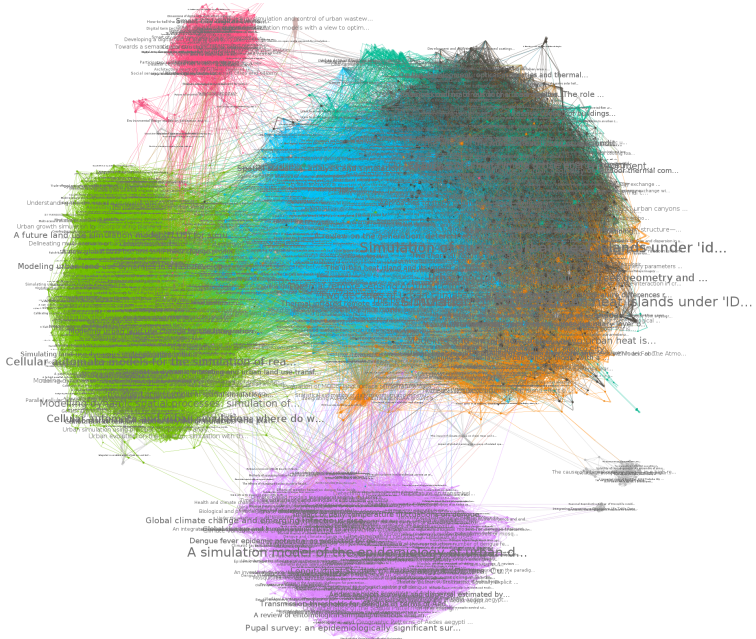
Research question:

Which effective links between the fields of urban digital twins and urban simulation, in terms of effective scientific practice? How do these links exist in terms of citation networks?

→ scientometric analysis of citation networks of these literature streams.

- collection of bibliographic data from google scholar, using open source data collection tools developed by [Raimbault et al., 2020]
[Raimbault, 2019]
- initial queries: “urban digital twins”, 100 papers; “urban simulation model”, 100 papers
- reconstruct backward citation network (“cited by”) up to depth two
- citation network with 99562 papers, 182479 citation links, with basic metadata (title, authors, year); average degree 3.7
- remove single branches to keep network core: 29755 papers and 112670 links

Citation network



Main fields

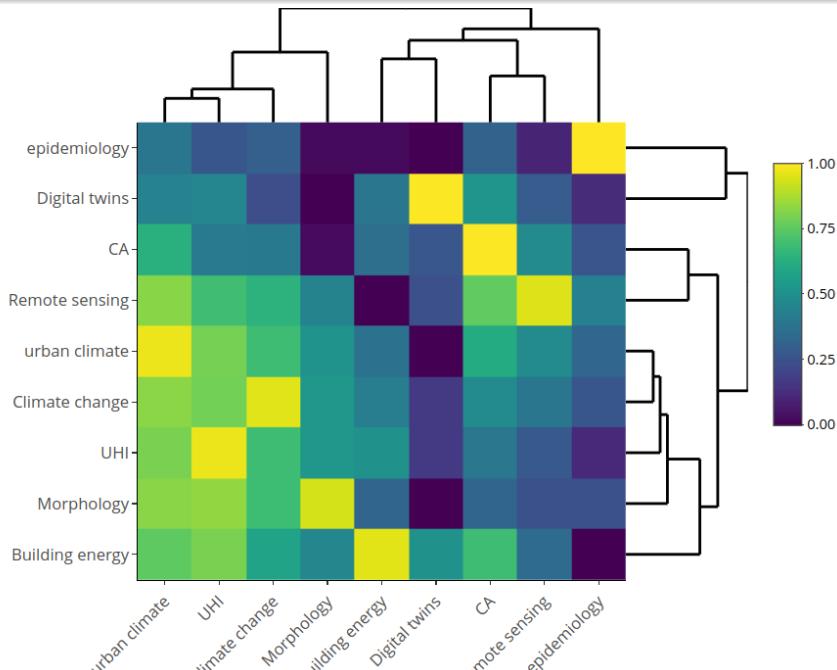
Communities obtained through modularity maximisation (directed modularity 0.657):

- Epidemiological simulation - 21.5%
- Urban Climate - 20.9%
- Urban Heat Island - 18.4%
- Cellular automata and land-use change - 18.2%
- Climate change impacts - 8.87%
- Digital twins - 4.26%
- Building energy use - 1.98%
- Remote sensing - 1.78%
- Urban morphology - 1.35%

Proportion by initial query: simulation 28469, digital twin 576, both 710 → strong imbalance on terms of field size, good correspondence with endogenous communities.

Publication temporality: oldest year 2017 for digital twin (median 2022); oldest 1982 for simulation (median 2019)

Citations flows between fields



Results

- low integration in terms of scientific practice (citation flows), may be due to DT recency, or different communities of practitioners
- difference in terms of temporal and spatial scales may also hinder integration, while it is one reason for stronger links (long term territorial planning)

Perspectives

- modelography and systematic analysis of processes, time scales, model types, for a similar corpus; link it with a sociology of science approach
- simulation at the core of many DT definitions, crucial for sustainability application; can not be used in practice without systematic exploration and validation practices, methods and tools (see e.g. OpenMOLE)



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Weil, C., Bibri, S. E., Longchamp, R., Golay, F., and Alahi, A. (2023).

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