Temporal Aspects in Process Support for Urban Digital Twins

Position Paper

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Abstract

In this position paper, we follow the concept of timescapes in smart cities to explore the use of temporal features and data. Our main case is the use of digital twins, complex urban systems, and processes around them, in particular towards spatio-temporal information access and their use towards urban planning and climate transitions.

CCS Concepts

• **Information systems → Spatial-temporal systems**; **Information systems applications**; • **Human-centered computing**;

Keywords

Urban Transitions; Urban Digital Twins; Temporality; Smart Sustainable Cities; System of Systems; Multi-Stakeholder Digital Ecosystems; Climate Action; Spatio-Temporal Information Access

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1 Introduction

This position paper refines an earlier talk [2] and develops arguments and derives requirements in particular for scenarios in the context of spatio-temporal urban digital twins. Space and location are often the core dimensions around which smart city systems and urban digital twins are structured, and the temporal dimension is less developed or used only as a vaguely defined "present". This often goes hand in hand with data availability being much higher for spatially than for temporally coded data. One earlier driving observation was that "cities are full of spatial data, but more temporal insights are needed as process support" [2, 7]

To further develop the arguments, we structure this paper around the concept of "timescapes" in smart cities [6]. It helps to understand aspects of the temporal dimension in cities and urban development, especially the temporal changes in schedules, pace, and rhythms in smart cities, which we understand as socio-technical systems [3] and in this paper in particular as socio-spatiotemporal systems with sociospatial–temporal relations [6].

A result of increasing use of advanced technology and digitalisation is "time-space compression" leading to a reduction in distances in space and time, leading to faster reaction and travel times and increasingly up to the real-time city [5].

This finds an equivalent in domains of urban planning, which is bridging smaller time horizons and higher frequency of updates and planning, going down on the temporal scales from years and centuries down to days and minutes [4], which brings specific requirements with it for the process of planning, forecasting, and simulations and the integration of tools, methods, and data sourcing.

These developments drive the change towards more data-driven and data-supported urban planning. Information access and system development in (smart) urban environments can take many forms. In our understanding, Smart Cities include the aim for data-driven urban transformation in an inherently cross-disciplinary way. This includes developing and integrating systems and data sources, and aligning with city strategies and ensuring a consideration of public and social good.

2 Temporal aspects in smart cities

Some general spatio-temporal systems and approaches in smart cities can be summarises as the following.

- Time-aware IR/RecSys: spatial and temporal grounding, POIs & Opening hours, Event mining, Routes
- Time and space as first-class features in (semantic) data
- (Urban) Document analysis with temporal and spatial extraction
- Granularity and data quality
- Complex integrated queries (topic + location + time + context + transport)
- cross-domain complex scenario-based search and recommendation [1].
- Multi-modal Mobility
- Spatio-temporal mobility pattern analysis (and optimization)
- (public) transport options with time perspective
- Road closures, construction, emergencies, incident management etc.
- understanding use of space, identifying functional areas and hotspots,
- understanding temporal patterns in use of the city
- (Historic) City changes over time
- Targeted VGI (Volunteered Geographical Information) collection

They are mainly used to understand or manage the present in analytic or reactive real-time systems with usually only short forward planning time horizons. Analytics systems are being used for understanding city dynamics and improving urban systems. But using it for longer-term insights, for finding different ways to do planning, has still a lot of potential.

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Digital Twins in their easiest form are 3D models of the city, and they can be expanded by including different data sources and plugging in different prediction models.

While for individual city systems, main concerns include the systems themselves, data accessibility, open data, and integration into open ecosystems for stakeholders and users; urban planning includes different systems, domains, scales, governance issues, etc. In general, these are specialist systems, but the ambition is to use them for improved citizen participation and a better understanding of the outcomes of different planning alternatives and their impacts on different types of metrics through visualisation.

An important use case is Digital Twins for energy transition and climate action and to support integrated urban planning and participation in scenario-driven ways. Efforts to create sustainable and resilient cities are central to ongoing urban transformations.

- Digital Twins and support for climate neutral and liveable cities
- Urban planning and scenario simulations, decision support
- Improved participation, more informed decision-making, and insights into longer-term impacts
- Inhabitant responses and sentiment analysis to short- and long-term urban planning interventions
- digital support for climate neutral and liveable cities
- Sustainability, Decarbonisation support, Green shift, Climate action
- Energy and mobility modeling and analysis
- Integrated urban planning with energy and mobility planning, societal masterplans, district planning, building codes, etc.
- Impact Assessment & Feedback learning loops

These topics are all related to strategy development and planning in cities. Processes around city planning include the ways that strategies are developed and negotiated, and participation processes are set up and supported by different methods, processes, and tools.

Coming back to the concept of timescapes, simulation, planning, and policy happen on different time horizons, as well as any potential feedback loops within the direct planning processes. The same holds for the much more difficult aspect of potential later evaluations on whether these plans reached their goals. The move towards the real-time city as discussed above is then also reflected in the increasing granularity of data, both spatial and temporal, and the frequency of data sampling, but critically also the frequency of data analysis and forecasting.

For example, for both mobility and energy simulations, they can go from minute or hourly simulations to understand smaller patterns, but usually the larger aim is in metrics that also need their aggregation on a monthly or yearly basis which can then support decisions from multiple alternatives. More detailed and short-term simulations are especially needed in mobility scenarios to understand, optimise, or restructure traffic flows or in energy scenarios. However, on a longer term, there is a need to assess the expected future impact of interventions. So both the cycles of analysis and their time horizon for predictions, for planning, for modeling, for forecasting, for decision-making, and surrounding processes is changing.

The integration of different prediction models into a broader view can also help to not do only one intervention, but understand side effects and second order effects in a longer term, or allow to include more positive impacts into one specific intervention by being able to model their mutual dependencies better.

A very long term ambition would be a more explicit and well modeled impact assessment and feedback loop that would allow a tight learning loop from interventions to be able to compare them to original plans and expected impacts and use that to accelerate transitions. On the other hand, many pilot interventions happen on a small area scale and as small time-limited pilots. Structured data sources for assessing impact, such as emission, mobility, or population data, may be only available at a larger geographical scale such as the whole city without a way to disaggregate it to the intervention area. There may also be mismatching temporal scales, which may not be sufficiently visible in available data or statistics (which often become available with a delay of up to 1-2 years), not labeled, or not available. Having these larger feedback learning loops could help to understand why plans were originally developed in a certain way and then also being able to follow up on why specific pilots worked or not. Such approaches would also close the loop to document analysis as a strong focus of temporal retrieval.

3 Conclusion

While cities are still mostly understood as place-based, the way we use them is also very much temporal. Future urban planning and scenario building through digital tools, digital twins, and information access systems will have to take the temporal dimension into account to develop better systems to deal with our urgent societal challenges around the urban and climate transformations.

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