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Luca Tom Bauer
Universität Bremen, Germany, bauerl@uni-bremen.de

Robin Fritzsche
Universität Bremen, Germany, robfri@uni-bremen.de

Gerhard Klassen
Universität Bremen, Germany, gklassen@uni-bremen.de

Dulce Maria Villegas Nuñez
Universität Bremen, Germany, villegas@uni-bremen.de

Björn Niehaves
Universität Bremen, Germany, niehaves@uni-bremen.de

Cultural Digital Twin Cities – Accessing cultural city data from unstructured sources

Research in Progress

Luca T. Bauer[1], Robin Fritzsche[1], Gerhard Klassen[1], Dulce Maria Villegas Nuñez[1], and Björn Niehaves[1]

[1] University of Bremen, Fachbereich 3 - Mathematik und Informatik, Bremen, Germany
{bauerl,robfri,gklassen,villegas.de,niehaves}@uni-bremen.de

Abstract. This working paper explores the concept of cultural digital twin cities, proposing a novel approach to incorporating cultural and social data into the digital modeling of urban environments. Recognizing the limitations of current digital twins, which largely focus on physical and infrastructural elements, this work in progress paper emphasizes the significance of uncurated data sources, such as open street map imagery, social media conversations, and its metadata. This approach not only enhances the understanding of urban life beyond tangible aspects, but also includes currently inaccessible aspects of the city in urban development. The paper sets a foundation for future research, development of frameworks, and software dedicated to the realization of 'other' digital twin cities, aiming to bridge the divide curated and uncurated urban dimensions.

Keywords: digital twin city, cultural digital twin, smart city, digital twin, urban planning

1 Introduction

In digital times, the smart city is at the core of citizen centric policy. It is modeled on a structural digital copy, often lacking a cities socio-cultural fabric. Policymakers' vision and reality are seldomly congruent. Wanting to create data-based policy for their citizens, policymakers need to get as close of a model of their living space as possible. This purpose is currently often achieved by creating digital twins of the city (Kitchin, 2014). However, these often only reflect the tangible surface area, leaving behind all social and cultural dimensions (Allam & Newman, 2018).

In our research we assess how to use uncurated data to generate a holistic picture of the culture of a city through the visualization in a digital twin. In this working paper, we give a theoretical background and propose exemplary use cases to build upon, where digital twins have a utilization for the social fabric of a city (Brumana et al, 2023). From recent research, we deduced that a combination of the structural and unstructured dimensions could be a vital step to a better understanding of the social fabric and culture of a city (Allam & Newman, 2018). Cultural digital twin cities could be a tool that may revolutionize conceiving a city. For this we assessed three examples on how to approach the development.

Based on this, our working paper is guided by the following research question (RQ): *How does current research use uncurated data to assess cultural dimensions of digital twin cities?*

2 Theoretical Backdrop & Methodology

We employed a comprehensive literature review to explore current trends in research on the intersection between digital twin cities (DTC) and the cities' culture mapped on digital models (Schreibmeier et al, 2020). As this is a work in progress, the depicted methodology is purely literature review. Following, we introduce practical publications for scoping the topic and show synergies between currently seldomly linked concepts.

For this purpose, we did a systematic search of databases such as JSTOR, SCOPUS, and Google Scholar using a predefined set of keywords relevant to our study's focus. For this purpose we mapped a assessed a total of 922 publications Scopus and 1162 JSTOR publications using the search string *("digital twin" AND "culture") OR ("digital twin" AND "cultural") OR ("smart city" AND "culture") OR ("smart cities" AND "culture")*. Exclusion criteria were set to omit non-peer-reviewed articles, editorial comments, and studies not directly addressing the core themes of our investigation. The presented working paper solely depicts the theoretical background upon which current tool development and research processes are based.

2.1 The Smart City and its Digital Twins

Smart cities are generally seen as a change of paradigm regarding urban development. Even though they lie at the intersection between three strongly discussed issues of public policy, urban development and digital transformation, their concepts are often one-size-fits-all, lacking empirical and strategic depth (Kitchin, 2015; 2022). This is especially visible when looking at non-economic or intangible infrastructure.

Smart cities mostly revolve around citizen-centric urban development and participatory projects (Capra, 2016; Cardullo and Kitchin, 2019). Planning and operating a smart city as such is not only a bureaucratic and political project, but one of public-private partnership including every party concerned (Liu et al., 2021). They are meant to enable policymakers and citizens alike (Bunders and Varró, 2019; Portmann and Finger, 2015; Roche et al., 2012). The same applies to scholarly work. If the public sector aims to provide best possible, most need-based services to the city's residents, it needs to consider research from all disciplines, be it political sciences, information systems, engineering, sociology, architecture, anthropology, urban planning or many more. As Kitchin noted, there are many concerns to be addressed, like "[…] *the politics of big urban data, technocratic governance and city development, corporatization of city governance and technogical lock-ins, buggy, brittle and hackable cities, and the panoptic city*" (Kitchin, 2014). Here we see a need to not only apply their respective frames of reference to a given object, but rather to follow their lanes of research and identify uses of smart cities to address their challenges.

In the frame of smart cities, an often-used concept for policy creation is the digital twin. In the early 2000s (Grieves and Vickers, 2017), the concept of 'digital twins' emerged as a transformative paradigm in various domains, ranging from manufacturing

and healthcare to urban planning and beyond. Digital twins represent a virtual counterpart or replica of a physical entity, system or process. In the rapidly evolving landscape of smart cities, the integration of cutting-edge technologies has given rise to the DTC, providing a virtual counterpart to physical entities and systems. A DTC describes the implementation of digital twin technologies on an urban scale (Deng et al., 2021). The foundational idea involves creating a comprehensive, digital replica of a city's infrastructure, allowing for advanced analysis and data-driven decision-making.

Scientifically, the utilization of digital twin cities has been explored in various domains, including forecasting, simulation, and crisis management. Noteworthy examples include their role in handling health data during the COVID-19 pandemic (Ford and Wolf, 2020) and optimizing energy resources (Francisco et al., 2020). Deng et al predict that the development of digital twin cities will establish a new management paradigm, enabling the tracing of past events and the exploration of future directions - a trend expected to shape future research in this domain (Deng et al., 2021).

Still, in establishing a new paradigm of smart cities, what is often left behind is the social fabric and culture of the city as it cannot easily be depicted in the logic of a technological, mostly economic digital twin (Allam and Newman, 2018). Here we see an untapped potential that could be realized by identifying data sources that can map out the social fabric of a city. This social fabric is sometimes not immediately visible in official data as it often comes from counter positions to prevalent political positions (Burns and Andrucki, 2021). To make this social fabric visible is an ambitious task as culture is an often-intangible concept. The successful creation of a cultural digital twin of a city could have many benefits. On the one hand a new tool to inform policies. On the other hand, a better way to understand the life and culture in a city.

2.2 Culture in the City

Striving to access a city's cultural makeup through a digital twin, there is a need for a pragmatic understanding of culture. We need a definition of culture that can be used to identify which data can represent the culture of a city. The term culture has undergone many changes in the course of history and is often described as an overly broad and ambiguous concept (Song, 2005). Striving to define the term we see an opportunity to include a broad spectrum of versions of culture. Lenard identifies four approaches to define culture. These approaches are culture "*-as-encompassing-group; -as-social-formation; -as-dialogue and -as-identity*" (Lenard, 2020). Culture-as-encompassing-group can be understood as an encompassing value system that provides guidelines which provide the context for choice and meaning for members of a group. This account is criticized for drawing boundaries of a culture as determined and unchanging (Moore, 2019). Culture-as-social-formation is an approach that tries to react to the critique of the culture-as-encompassing-group account but at the same time tries to retain most of its content. It understands culture as the shared experience of group members being subject of the same social formations and institutions. This approach acknowledges that culture has the tendency to change and develop over time. Culture-as-dialogue defines culture by the interaction of the members of a group and their engagement with each other. This account has the actions of the group members and their capacity to shape their culture in its focus. Culture-as-identity describes an account that sees an overlap between the concept of identity and the concept of culture. The things we identify with

describe our culture. This account is preferred by some scholars as it incorporates a wide variety of cultural forms (Eisenberg, 2009).

We chose the conception of culture specific to the context of cities and decided to work mainly with the culture-as-identity account, as we think that it is most inclusive to bottom-up initiatives. When understanding culture as identity or identification, we can infer that something is culturally relevant if people identify with it, exemplary social events such as festivities, traditions, or monuments people frequently visit, as well as create themselves through, i.e. street art.

To understand which data is feasible for this purpose, we need to understand that the data of a city can be fit into two dimensions: structured and unstructured dimensions. The structured dimension depicts what is usually associated with tangible and curated infrastructure, mobility, and economic data. The unstructured city on the other hand, is less palpable (Laguerre, 1994). It, rather than being a documented, is the organic socio-political fabric (Hernández and Kellett, 2010). Oftentimes the data that can be identified as unstructured is data that is not curated or provided by city or corporate officials. It can for example be social media data or crowd-sourced data. It is *"[…] the shapeless areas of the city where economic and socio-political structures are particularly unstable*" (Hernández and Kellett, 2010). As such it can been seen as the organic fabric between structural components. To approach the identification with events or physical entities in cities, we identify currently unstructured data as a very important source.

The culture visible in this manner often shows data that goes against the focus of outward visible digitalization initiatives (Jiron et al., 2021). Our aim is to use unstructured, uncurated data to generate a holistic picture of the social parts of a city. Especially the social spaces of a city are often created, as their progenitors act on them out of a feeling of being left behind. As such, beside bottom-up initiatives, the whole city must be made accessible for policymakers for more inclusive urban development.

2.3 The Cultural Digital Twin City

For accessing current potential research on cultural digital twin cities, we conducted SCOPUS searches on the last ten years with the keywords "digital twin city" (69), "digital city twin" (2), "culture" AND "digital twin" (109), as well as "cultural" AND " digital twin" (219). Even though over 400 publications were identified as potentially useful, most of them revolved around cultural heritage preservation, which is used for historical and architectural documentation purposes, but is not of use for assessing the unstructured parts of a city in a digital twin (Buonocore et al 2023; Mylonas et al 2023; Brumana et al. 2023; Sang et al. 2022; Banfi et al. 2023). Other publications revolved around social dimensions of cities in the sense of slums and settlements that are not scheduled in official city records (Khawte et al. 2022). Our research agenda understands the holistic city as the data about a city that is not curated and not provided by city officials or corporations. This can partly include settlements, but it is rather the social fabric dimension of the city that we are interested in. None of the publications developed a digital twin with this type of data of a city. We concur this as a gap in current research and see a need for a comprehensive framework. In developing a framework, we want to focus on technologies and use cases that could be beneficial in creating a CDTC.

3 Use-Cases for Cultural Digital Twin Cities

In this chapter we identify the use and current use cases of Cultural Digital Twin Cities (CDTC). CDTC can be seen as an asset for cities on many levels besides policymaking. They enable better social and cultural policy, they can be used to attract tourists and to shine a light on culture, art and traditions that are neglected in classical city guides (Sang et al. 2022). This could open a new and innovative pathway to understanding city art and culture. The technology can be identified as a vital step towards more representation and therefore more participation. Furthermore, digital twins can be used to enhance future city planning to preserve this cultural heritage against external influence (Caprari et al 2022, Mylonas et al. 2023). In this we see direct impact in urban planning processes to integrate and visualize

As visible, there is a current gap in CDTC-modelling regarding the unstructured city. Even though a coherent frame is lacking, we identified examples of data sources as most relevant empirical cases. We chose them, as they are both the most tangible with actual use for policymakers and they also show innovative capabilities for accessing cultural dimensions in a CDTC. Other examples often were either vague or did not provide practical solutions, but rather ideas. The most promising examples of data that could be useful in developing a CDTC are the following: 1. openly accessible street view data (Hao et al. 2022), 2. social media conversations data (Schreibmeir et al. 2021), 3. social media geo-tags metadata (Sicari et al. 2021). We have chosen these studies based on their innovativeness in applying technology on data.

Hao and Wang's paper introduces an approach to creating a Digital Twin (DT) for urban environments using computer vision and openly accessible street map imagery. Their framework aims at inventorying facilities across various types and locations by employing a DeepLab V3 semantic segmentation model, which is pre-trained on the CityScapes dataset. By detecting curb facilities from GSV images and using Inverse Perspective Mapping (IPM) to estimate their spatial locations, the researchers can aggregate and filter these estimations to build a comprehensive digital inventory. (Hao et al., 2022). They use uncurated data, but it is not for the purpose of building a CDTC. We could use their methods to identify changes over time in street structure and widen their approach to e.g. street art.

Schreibmeir and Malaiya's paper introduces an approach of analyzing social media conversations with natural language processing to build a digital twin. Their study employs social media data to construct a digital replica and simulate the spread of an invasive species across the United States. By merging socio-material assemblage theory with digital twin technology, they developed machine learning algorithms and an initial digital twin model to forecast the movements of these pests (Schreibmeir et al., 2022). This approach of using social media discussions in combination with natural language processing and machine learning could be a promising way to map out culture in form of things people identify with in discussions under social media posts in a digital twin of a city, especially combined with picture-place recognition. To use this for our CDTC we need to develop indicators of identification in discussions linked to locality.

Sicari et al. use geotagging metadata of social media posts to construct a platform for enhancing 3D virtual indoor navigation (Sicari et al., 2021). In the case of cultural digital twin cities this could be an analysis of frequency or absolute number of geotagging metadata assessed by places in the city. From this information we infer

identification with specific places or sights. But to be able to make this inference we need to compare if the pictures containing the geotagging have similar parts of a place e.g. monuments, graffiti, natural scenes in it. For this we could incorporate neural network-based picture classification and pairwise comparison.

These three studies represent examples of which technologies could be used to assess the cultural dimension of a city. By synthesizing their approaches, it can possible develop a robust and multifaceted CDTC. This integrated model may not only document and preserve the cultural heritage of cities but also provide valuable insights for policymakers, urban planners, and cultural institutions. Nevertheless, a functional link is currently missing. All solutions presented provide value but are not possible to link in a user-friendly manner. For deeper impact an interoperable framework will be necessary on which visualization tools can depend.

4 Discussion and Outlook

As modern cities become increasingly more digital a holistic picture of the life and culture in a city is needed. This study highlights the growing digitalization of modern cities and the consequent need for a more comprehensive representation of urban life that encompasses all dimensions. Despite the advancement of digital twin technologies in capturing the physical and infrastructural aspects of cities, there remains a significant gap in their ability to represent the cultural fabric of urban environments.

Answering the RQ: *How does current research use uncurated data to assess cultural dimensions of digital twin cities?*, we introduced the concept of cultural digital twin cities as a solution to bridge this divide by integrating unstructured dimensions of city life through various uncurated data sources. This approach not only offers a more comprehensive view of urban environments, but also empowers citizens to engage with their city in ways not dictated by policy mandates.

Furthermore, our research lays the groundwork for future investigations into the application and impact of cultural digital twin cities. Regarding further research we plan to incorporate the identified methods and technologies on different uncurated data sources. This will be the next step in building a comprehensive Cultural Digital Twin City. Further research and application will be based upon the currently still in development DIN-SPEC 91607 for urban digital twins. Nevertheless, data on not only feasible, but most relevant use-cases for urban planners is inaccessible. Throughout our literature review, we were unable to find a empirical studies based on needs as articulated by citizens or urban planners. Creating a coherent framework for CDTCs technological capabilities will need more empirical data and the why's, not only the what's of integrating uncurated and cultural data.

In summary, our research presents a forward-looking perspective on the digital representation of cities, advocating for a more inclusive and culturally rich approach. By bridging the gap between the often seen as antagonistic dimensions of urban life, cultural digital twin cities promise to enhance the comprehensiveness, accuracy, and utility of digital urban models, paving the way for more responsive and inclusive urban environments. Nevertheless, singular approaches like the ones mentioned before, fall short in comparison to the overarching goals. Not interoperable solutions allow for first assessments but are unable to be linked properly.

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