Digital participatory mapping in urban research

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Abstract *Digital participatory mapping tools provide opportunities to combine the spatial analytical research tradition with the analysis of citizens' subjective, place-based experiences and knowledge. This introduction to digital participatory mapping methods emphasizes two main perspectives into their contributions to interdisciplinary urban research. First, the contribution outlines the origins of digital participatory mapping as a reaction to the positivist paradigm of geographic information science and the consequent interest to challenge and diversify the types of knowledge represented in geographic information systems (GIS). The development of participatory mapping tools using digital mapping interfaces has enabled the large-scale inclusion of subjective, citizen-produced geographic information into GIS and introduced relational and reciprocal representations of space into geographic information science. Second, the contribution discusses the advantages of digital participatory mapping methods in bridging social-scientific research with the spatial-analytical traditions of geographic information science. Digital participatory mapping methods have been used to introduce the analysis of spatial trends, patterns, and relationships in disciplines without a strong research tradition in spatial analysis. In urban contexts, such uses include the mapping of individual´s spatial practices, mobility, perceptions, and evaluations related to the urban environment.*

Keywords *Digital participatory mapping; public participation GIS; geographic information systems*

Introduction

Digital participatory mapping merges the participatory mapping tradition from human geography with the spatial-analytical approach of geographic information science. Despite the range and variety of digital participatory mapping tools available today, methods developed in different contexts and for different uses share a common aim of capturing spatial knowledge of lay participants as geographic information that is compatible with the data structures of geographic information systems (GIS). In urban research, participatory mapping tools with digital mapping interfaces have enabled the collection and analysis of subjective, place-based experiences

on spatial scales extending to city-wide and regional analysis and the joint analysis of such data with institutional sources of geographic information. This book contribution provides a basic introduction to digital participatory mapping with a focus on interdisciplinary aspects inherent for such methods as well as their use across different disciplines addressing urban issues. The contribution begins with an overview of the family of digital participatory mapping methods and concludes with a case that illustrates the use of a specific digital mapping method, public participation GIS (PPGIS), in a recent research project in the Vienna Metropolitan Area.

Origins of digital participatory mapping

The academic interest in technologies involving citizens in the production of spatial information developed in the 1990's in response to the early epistemological critiques of GIS. These critiques, rooted in the origins of geographic information science as a computational discipline, perceived the technology and its representational capabilities as an inherently positivist form of knowledge production and expressed concerns about uneven access to GIS, spatial data, and the ability of the technology to represent complex spatial phenomena (Elwood 2006; Kwan/Knigge 2006). A primary concern was that spatial decision-making relying on GIS would lead to the marginalization of people, places, and knowledge that were not adequately represented in GIS (Elwood 2006).

Over the past three decades, diverse methodological approaches have emerged to depict subjective human experiences in a GIS environment. These approaches have been motivated, on the one hand, by the aforementioned critical debates and the aim to incorporate knowledge produced by non-experts into GIS. On the other hand, they have been spurred by the analytical and research opportunities arising from the exponential increase in the availability of geospatial data produced as a by-product of the digitalized aspects of day-to-day life. Despite their shared foundation in geographic information science, these approaches have originated from diverse disciplines, diverse geographic contexts, and have been developed to address varying knowledge needs. Nevertheless, they share a common goal in expanding the types of knowledge and voices present in the development and use of geospatial technologies and data.

Brown and Kyttä (2014) provided a broad overview of this literature by identifying three distinct methodologies that integrate participatory mapping and GIS: participatory GIS (PGIS), public participation GIS (PPGIS), and volunteered geographic information (VGI). They argued that while PGIS and PPGIS share many similarities, these methods differ on some key characteristics, such as the context in which they have been developed and the dominant mapping technology used. PGIS approaches seek to foster community engagement and empowerment by document-

ing local knowledge in a format that can be imported into GIS alongside institutional sources of geographic information. They often utilize paper maps in collective mapping exercises that are later digitized. In contrast, PPGIS approaches are characterized by a focus on individual participation through digital mapping interfaces, urban populations, and the use of the produced data in planning. The development of PPGIS approaches has been motivated by the aim to broaden public involvement in urban planning and increase the use of non-expert spatial knowledge in spatial decision making (Brown/Kyttä 2014). Last, VGI encompasses a broad spectrum of user-generated geographic information that has been actively volunteered by people in the form of collaborative mapping (e.g., OpenStreetMap) or produced by diverse online services, apps, and social media platforms that collect spatial information (Neis/Zielstra 2014).[1]

Following the rapid development of new participatory mapping technologies and the growing availability of geographic information generated through location-based apps and social media, user-generated geographic information is increasingly framed based on the individual's role in data production. Here, a broad distinction can be drawn between active and passive sampling approaches for acquiring citizen-produced geographic information (Grêt-Regamey et al. 2021). The former includes individuals' active contributions in collecting geospatial data with methods such as PPGIS or geographic ecological momentary assessment[2] (Mennis et al. 2018) and the latter geographic information produced as the by-product of other processes, such as spatially referenced mobile phone or social media data. As the availability and access to data produced with passive sampling approaches increase, active sampling approaches are likely to develop towards addressing more specialized knowledge needs that require active engagement with the survey topics and contents (e.g., combining existing social-scientific survey items with spatial information derived from mapping activities). Moreover, studies comparing participatory sources of geospatial data collected with both passive and active data collection methods suggest that these approaches produce distinct results and excel in fulfilling different knowledge needs (Depietri et al. 2021; Heikinheimo et al. 2020; Stahl Olafsson et al. 2022). For example, Depietri et al. (2021) compared the capabilities of active and passive sampling to capture cultural ecosystem services. They found that while a social media-based approach was effective in characterizing areas with high visitation or touristic value, PPGIS was better suited for describing areas with lower visitation but high value among local users.

1 Outside this broad division, the terms PGIS and PPGIS are sometimes used interchangeably. For an overview on their conceptual orgins, refer to Sieber (2006).

2 Geographic ecological momentary assessment (GEMA) involves repeated sampling of participants' experiences, evaluations, and behaviours combined with GPS location and provide increased spatial accuracy in linking participant experiences with environmental exposure.

Digital participatory mapping in interdisciplinary urban research

In research use, the strengths of participatory mapping are found in its ability to gather and represent spatial experiential knowledge embedded in local human-environment relationships and based on the participants own lived-in experiences. Digital participatory mapping approaches differ from traditional participatory mapping methods employing paper maps in some key aspects that characterize most, but not necessarily all, approaches. These include the aim to integrate the produced information in GIS, the applied data collection strategies, and the use of digital mapping interfaces and platforms for data collection.

Representational capabilities

Participatory mapping methods enable the mapping of various spatial attributes ranging from places for everyday behaviours to more subjective place-based experiences and evaluations. In contrast to some participatory mapping approaches (e.g., mental mapping) that use relational representations of space to convey spatial information (Kogler 2024 in this book), digital participatory mapping approaches typically seek to represent the gathered information in a GIS that relies on absolute, cartographic representations of space. In GIS, a shared geographic reference system is required for combining multiple sources of geographic information, conducting diverse spatial analyses, and identifying spatial patterns and commonalities. Moreover, a shared geographic reference system provides compatibility with GIS-based planning support systems in land-use planning and urban design.

While confined to these representational limits, GIS incorporating lay knowledge can also broaden the view of place in geographic information science from a locale to being actively constructed and filled with subjective meaning (Merschdorf/Blaschke 2018). Participatory mapping data representing an individual's subjective experiences thus merges both absolute and relational representations of space. From an analytical standpoint, such data can be examined not only based on its geographic attributes, but also on the relative importance attributed to it. Digital participatory mapping data portraying subjective spatial experiences thus offer novel opportunities to study relational, reciprocal views of space within urban research.

Critical assessments of digital mapping practices draw attention to the challenges in portraying subjective knowledge with the representational capabilities of GIS and the limitations of common vector entities (e.g., points, lines, and polygons) in capturing complex spatial processes and human-environment interactions (Huck et al. 2014; Sieber 2006). However, others argue that, despite spatial variability caused by the choice of the used geographic feature and its ability to represent the intended spatial phenomenon, the spatial precision of mapped data is still

sufficient to support most urban and land-use planning applications (Brown et al. 2020). Several studies have also explored the mapping of media beyond location mappings, including studies collecting soundscapes (Korpilo et al. 2023) and participant-uploaded photographs (Nummi 2018).

Advantages and limitations of digital mapping interfaces

In comparison to paper maps that have a fixed scale, level of generalization, and geographical extent, digital base-maps are typically scalable and let the user to zoom in and out as well as to pan the base-map. This allows for larger mapping scales covering extensive geographical areas as well as the inclusion of multiple, separate, mapping scales, contexts, or base-map types within a single survey. In urban research, digital participatory mapping tools are used on diverse scales, ranging from individual buildings or public spaces (Harsia/Nummi 2024) to neighbourhood (Kyttä et al. 2013) and regional scales (Bijker/Sijtsma 2017). The choice of the mapping scale and required mapping precision is generally related to the studied spatial phenomena – for instance, a mapping activity related to the perceived quality of the participant's residential environment can be expected to collect locations mapped in a smaller geographic area than an activity focusing on commuting behaviour.

Due to these technological advantages, digital mapping approaches excel in uncovering scale effects in diverse human-environment interactions and capturing social and environmental processes taking place and interacting at diverse spatial scales. Multiple studies have applied digital participatory mapping methods to explicitly identify scales relevant for specific spatial processes and to understand how spatial relationships between people and places change across different spatial scales (Bijker/Sijtsma 2017; Brown et al. 2015). For example, PPGIS studies focusing on place attachment (Brown/Raymond 2007; Brown et al. 2015) have been able to empirically dissect how the spatial characteristics of an area that an individual feels a connection to may vary between people and places.

The technological aspects of digital participatory mapping are linked to both the key functionalities of these research tools as well as their limitations in research use. Concerns about the digital divide and the influence of the mapping technology on the type and quality of the produced data characterized much of the early critical discourse on digital participatory mapping (Harris/Weiner 1998; Obermeyer 1998). Over the last decades, advancements in the usability of commercially available digital mapping tools and the increased digital skills among urban populations have, to some extent, alleviated these concerns. Additionally, studies focusing on the usability of digital mapping tools among groups traditionally impacted by the digital divide, such as older adults, suggest that usability can be improved by adequate prelaunch testing, adapting the survey design for group-specific needs, and providing appropriate support materials for the respondent (Gottwald et al. 2016; Poplin 2015).

Nevertheless, digital divides persist in studies with sampling strategies that rely on online visibility (e.g., social media, adds on websites or newsletters) and are thus likely to attract participants that are already active on online platforms (Blank 2017).

Data collection strategies

Studies collecting primary research data using digital participatory mapping tools follow diverse sampling and data collection strategies. Purposive sampling is employed both in PGIS and PPGIS approaches to ensure the inclusion of key actors or groups in the sample. However, as the digital survey interfaces of PPGIS tools offer opportunities to scale up data collection by reaching respondents whose participation is not restricted by their geographical location, PPGIS surveys are also conducted using convenience sampling strategies that maximise the number of prospective respondents. Passive approaches for collecting user-generated geographic information rely primarily on convenience sampling. Thus, while these data sources may offer large datasets in terms of both size and geographic coverage, they typically include considerable biases in terms of the represented population (Blank 2017).

In research use, PPGIS approaches are often combined with probability sampling aimed at maintaining population representativeness and minimizing biases in the sample (Brown/Kyttä 2014). PPGIS studies using purposive sampling tend to display sampling biases similar to many social scientific surveys, with overrepresentations of especially groups with higher levels of formal education (Brown 2017). Such studies, like all social scientific surveys targeting large sectors of the population at once, are likely to miss the voices of some underrepresented or vulnerable groups. To reach these groups, data collection strategies and surveys tailored specifically for these groups are needed (Harsia/Nummi 2024).

Empirical use in urban research

From an interdisciplinary perspective, digital participatory mapping provides diverse opportunities to bridge research fields without an explicitly spatial approach with the spatial-analytical traditions of geographic information science. Digital participatory mapping tools are not inherently tied to specific epistemologies and can be employed in quantitative, qualitative, and mixed method research. However, most studies using digital participatory mapping methods lean on their quantitative aspects, exploring the data with spatial analysis and descriptive or inferential statistical analyses.

In environmental psychology, digital participatory mapping approaches have been employed to study diverse human-environment interactions in place. In urban context, examples include studies focusing on the perceived quality of urban living

environments with study participants locating places with high or low functional, social, and aesthetic quality (Kyttä et al. 2013) as well as studies developing frameworks to map place attachment or sense of place (Brown et al. 2015, 2020). Moreover, the use of geographic ecological momentary assessment tools has forwarded the research linking environmental exposure with specific cognitive responses, such as reductions in stress levels (Mennis et al. 2018).

Ecological and conservation studies have employed digital mapping tools to combine human experiences, such as landscape values and ecosystem services with landscape and ecological analysis. These have forwarded especially the empirical study of diverse cultural ecosystem services, as mapping tools have provided opportunities to assess and quantify subjective place values that people associate with natural environments, such as aesthetic and spiritual values (Baumeister et al. 2020; Brown/Fagerholm 2015; Depietri et al. 2021). Related topics have been explored in the field of environmental health promotion among studies focusing on the health-supportive aspects of urban and natural environments. Here, studies mapping the use of urban green and blue spaces have introduced analytical approaches to identify spatial patterns in their use (Bijker/Sijtsma 2017; Heikinheimo et al. 2020) as well as located diverse subjective health benefits associated with these environments (Brown et al. 2018). Such studies have also been able to integrate perspectives of environmental justice to assess equity in access to diverse health-supportive environments, such as public green and blue spaces (Raymond et al. 2016).

Moreover, studies focusing on urban sustainability transitions and urban liveability have employed digital participatory mapping approaches to explore the use of sustainable modes of transportation (Ramezani et al. 2021) as well as to map perceived environmental barriers and facilitators of urban environments supporting sustainable modes of transport, such as walking or biking (Czepkiewicz et al. 2016). Travel behaviour research and studies focusing on urban mobilities have used participatory mapping tools to model individual activity spaces (Hasanzadeh et al. 2017) and to examine changes in the use of urban spaces over time (Champlin et al. 2023). These research fields have benefitted especially from the increasing availability of user-generated geographic information produced through social media and apps using geolocating services. In urban research, such data sources provide increased temporal and spatial accuracy in examining various spatial practices. For example, diverse sources of volunteered geographic information are used to examine flows of people in urban space, such as commuting behaviours (Hadachi et al. 2020) or the recreational use of public open spaces (Heikinheimo et al. 2020).

Finally, the use of digital mapping tools in participatory planning processes itself has been the focus of active inquiry within studies focusing on participatory practices in urban planning (Kahila-Tani et al. 2016; Kantola et al. 2023). Such themes have been addressed especially in the PPGIS literature, as the integration of citizen-produced information to support spatial decision-making along expert-

produced materials has been a key motivation in the development of PPGIS tools. Transdisciplinary studies involving action research have, for example, involved planning practitioners in the development of best practices to integrate citizen-produced geographic information into urban planning practice (Rossi et al. 2024). Furthermore, some studies have employed digital mapping tools with a specific focus on mitigating conflicts in land-use planning, such as observing ›not-in-my-backyard‹ attitudes towards urban planning interventions (Brown/Glanz 2018) or identifying planning areas with conflict views on future development among different actor groups (Kahila-Tani et al. 2016).

PPGIS methods in urban research: a case study in Vienna, Austria

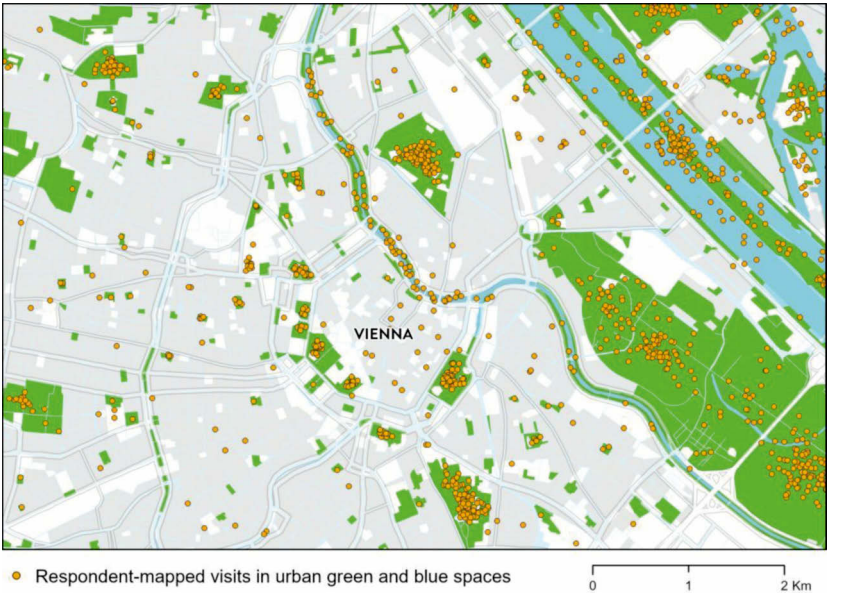
This section exemplifies the use of digital participatory mapping by introducing a recent PPGIS survey conducted in the Vienna Metropolitan Area. The aim of the survey and the subsequent data collection was to gather primary data for the research project *CURB-The COVID-19 pandemic as a disruptive force for urbanisation*, funded by the Austrian Science Fund FWF and hosted by the Austrian Academy of Sciences. The research project employed a mix of qualitative and quantitative methods, including a PPGIS survey. The survey, titled as *Meine Wohnumgebung* (My Living Environment), was designed to collect a dataset integrating both social-scientific survey data at the individual and household levels and place-based information related to spatial practices following the COVID-19 pandemic. The survey was conducted using Maptionnaire, a commercially available PPGIS tool[3], and included both conventional survey (e.g., multiple choice and open-ended questions) and several mapping tasks.

Prospective respondents for the *Meine Wohnumgebung* survey were invited to participate following a sampling strategy aimed at ensuring an adequate representation of the study population among the survey respondents. A random sample of 16,000 individuals was ordered from the Central Population Register of Austria. In order to capture a variety of residential environments ranging from urban to suburban, an areal stratification was introduced. This involved allocating half of the sample members to the City of Vienna and the remaining half to the District of Mödling bordering Vienna to the southwest. Invitations letters, including a brief project overview and instructions on how to participate in the online survey, were sent to selected individuals. The survey, available in German and English, was open for respondents from May to June 2023. A total of 1,713 individuals completed the survey, resulting in a response rate of 11 percent. The respondents placed over 10,700 individual points during the various mapping activities of the survey.

3 For an overview of digital participatory mapping tools, refer to Burnett (2023).

As PPGIS data are produced by lay participants, the criteria used to assess the quality of expert-produced geographic information are often not directly applicable (Brown 2017). Instead, data quality (e.g., mapping precision and reliability) can be actively improved by survey design. Figure 1 visualizes results from one of the survey's mapping tasks where respondents were requested to locate urban green and blue spaces visited in their everyday lives on a base-map. For this task, instructions were provided to assist respondents in placing or deleting a point map feature and navigating to the chosen location through panning and zooming the base-map. Moreover, a base-map with detailed information on green and blue land use and infrastructure was selected to help locating features in green and natural environments. Prior to the data collection, the survey underwent testing by multiple users and on devices with varying screen sizes to ensure its technical useability and to mitigate potential data quality issues arising from unclear formulation of the mapping tasks.

Figure 1: Distribution of respondent-mapped visits in urban green and blue spaces in Vienna inner city. Project "CURB".



Source: Author

Outlook

This introduction to digital participatory mapping methods has emphasized two main perspectives on their contributions to interdisciplinary urban research. First, the book contribution has outlined the interdisciplinary origins of digital participatory mapping, which emerged in response to the early positivist paradigm of geographic information science and led to an increased interest in diversifying the forms of knowledge represented in GIS environments. Today, with the rapid technological development of digital citizen engagement tools and the increasing digitalization of participatory planning, this remains an area of active inquiry among contemporary digital participatory planning practices. Open questions remain regarding the challenges of organizing truly effective and collaborative forms of citizen engagement in digital spaces and, in terms of digital participatory mapping, the limitations of representational capabilities of these technologies and their implications for spatial decision-making. Furthermore, research gaps remain regarding the best practices for integrating citizen-produced geographic information into planning support systems alongside expert-produced geographic information.

Second, this contribution has emphasized the role of digital participatory mapping in facilitating interdisciplinary urban research by bridging social-scientific research traditions with the spatial-analytical practices of geographic information science. Digital participatory mapping methods have played a crucial role in advancing the analysis of spatial trends, patterns, and relationships within disciplines lacking an established research tradition in spatial analysis. At the same time, studies employing digital participatory mapping have introduced sources of citizen-produced geographic information in research fields that have established practices in working with institutional geographic information. In urban research, applications often include the mapping of individuals' spatial practices, mobility, and perceptions of the quality of diverse urban spaces.

The future development of digital participatory mapping as an urban research method will be shaped by the increasing availability of user-generated geographic information, overall digitalization of urban societies, and technological advancements in digital mapping technologies. Following the 'explosion' of big data available for research use, including diverse sources of user-generated geographic information produced through social media and apps using geolocating services, more research is needed to understand the main advantages and limitations active data collection methods such as PPGIS. At the same time, the digitalization of many aspects of societal life, coupled with the increased usability and availability of digital mapping tools, opens new opportunities to integrate digital mapping in urban planning and citizen science initiatives.

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