Mapping public space in urban neighbourhoods using OpenStreetMap data

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OpenStreetMap (OSM) enriches the exploration and study of urban landscapes. In this research project, we aim to use OSM data to investigate urban public spaces from a distributional justice perspective. While public spaces are acknowledged as an important resource for urban society, it becomes important, in light of ongoing trends towards privatization, commercialization, and festivalization, to critically observe and reflect on the extent to which resources, rights and opportunities regarding public space are distributed equally. The amount, accessibility, and character of public space can differ between cities and neighbourhoods. A quantitative analysis of public space could offer insights into the distribution and availability of public space. To this end, we propose a framework for the identification and categorization of these spaces based on OSM data. The framework aims to enable both the mapping of public spaces as well as an evaluation of the share of public space. We also hope to investigate the potential of OSM data. Some preliminary findings and an introductory overview of the research process, with an emphasis on its cartographic aspects, were presented in a previous publication [1].

The inspiration for this research is the so-called Nolli map, a map of Rome dating back over 250 years. Giovanni Battista Nolli, an Italian architect, engineer and cartographer, analysed the urban fabric beyond the structure of roads and buildings. In his work, titled 'La Nuova Topografia di Roma', Nolli mapped the interior and exterior spaces of Rome in high detail as a figure-ground map with contrasting dark and light sections. This distinction is commonly interpreted as a demarcation between private and public space. Since Nolli's time, the character and diversity of public spaces, as well as cartographic techniques have evolved significantly. In this research, we adapt some ideas behind Nolli's map to contemporary conditions based on open data and semi-automated geoinformation processing methods.

For this purpose, we operationalize the concept of public space as public accessibility. Public space research offers various approaches, definitions, and models, often considering multiple dimensions to define 'publicness,' with accessibility being one such dimension [2]. As one sub-aspect of this, the term 'public accessibility' refers to

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whether a space is open and available for use by the general public. For feasibility reasons, we ignore other accessibility aspects like visual access, reachability or accessibility specifically for people with disabilities in this research. We chose public accessibility as the defining criterion because it is the basic prerequisite for a potential use of public space, it aligns with the common interpretation of the historical Nolli map and it is well represented in the OSM dataset. As a matter of practicality, the analysis excludes buildings and focuses exclusively on elements on the ground-floor level.

As part of the framework, which can be understood as a strategic approach, we develop multiple methods for processing OSM data to prepare and clean the data and to identify, categorize, and ultimately visualize public spaces as a map. The methods are implemented as Python functions which are made available as an open-source script [3]. With the map visualization in mind, the goal of the data processing is an overlap- and hole-free dataset with polygons only. This is a vital consideration as OSM data often involves undefined areas, overlapping elements, and the use of not only polygons but also line and point geometries. Key steps in the data preparation and cleaning therefore include filtering out insignificant point and line geometries, converting road and path line geometries into polygons, and resolving overlapping polygons. Several assumptions are made in this process. For instance, road lines are 'polygonized' by buffering the line geometries with the road width. In cases where no width is specified as a tag, which is quite common, a standard width is assumed based on the highway type and adjusted according to other tag keys such as direction, lanes or cycleway. Towards the end of the data processing, overlapping polygons are refined by merging similar spaces into space types and by cropping the polygons based on the specificity of the space type, visualization requirements and the inherent relationships between the elements - specifically, which elements are usually located within another element in OSM.

Space type as an additional attribute alongside public accessibility serves as a source of information for the accessibility but also allows a more differentiated picture of the areas. The identification of the public accessibility of areas is conducted on three levels, sequentially analysing both tags and geometries of the OSM dataset in the following order:

1. Analysis through explicit public access tags: Tags indicating public access, such as *access*, *foot*, *opening_hours* or *fee*, are initially assessed. For instance, areas with restricted opening hours or those requiring an entrance fee are interpreted as having restricted public access while areas tagged as *public* under the *access* or *foot* key, where the *foot* tag is describing access permissions for pedestrians, are considered publicly accessible.
2. Analysis through tags and geometries representing barriers: Tags and geometries are analysed in order to identify barriers (e.g. fences, hedges, rails, buildings) and therefore inaccessible enclosed areas. For example a playground enclosed by a fence with a locked gate is interpreted as publicly inaccessible, even though this information might not be saved as an explicit tag with the playground feature.
3. Assumption based on the space type: In the absence of explicit access information on level 1 and 2, the public accessibility is assumed based on the space type which is derived from tags like *leisure*, *landuse* or *amenity*. For instance, parks are presumed to be publicly accessible, while roads are

deemed inaccessible as they can not be used as public space in terms of its social and political function.

For the purpose of testing and further development, we apply the framework to two case studies, each covering an area of 500 x 500 m in Vienna, Austria. While for urban areas a good data quality of the OSM dataset can generally be assumed [4], an examination with the ohsome quality analyst (https://heigit.org/big-spatial-data-analytics-en/ohsome/ohsome-quality-analyst-oqt) reveals a limited fitness-for-use for this specific application. According to the ohsome quality analyst models, the primary tags underlying the analysis - *access*, *foot* and *barrier* - are not sufficiently saturated in the city of Vienna. This assessment is confirmed by a preliminary application of the framework in the case studies, which uncovers wrong results in some places during a ground truth verification. Consequently, the existing OSM data within the case study areas are not adequate for conducting a comprehensive public accessibility analysis.

In response, we verified and expanded the OSM data in the case study areas through extensive on-site mapping. The data enhancement took place in two phases: an initial preparatory step that utilized orthophotos and the multipurpose area map of the City of Vienna, which is integrated in the iD editor, followed by on-site field inspections. During the preparatory mapping, we corrected primarily building geometries and delineated space types, particularly green areas. Field inspections, in contrast, concentrated on identifying relevant barriers and access points (such as fences, walls, hedges, gates and building passages), and validating previously mapped areas. We used geolocated photos and map-based notes to document on-site mapping activities. An initial map of publicly accessible space, based on existing OSM data, served as a baseline and reference for comparison. Alterations and additions to geometries and tags were implemented in the iD editor. Apart from data gaps, the field visits revealed that public access is not always clearly evident, for example, when signs designating private property and prohibiting access lacked clear spatial reference or when a fence had an opening along a trail. It becomes evident that the lived and the legal sense of public space can differ from one another. Following OSM's ground truth paradigm [5], we mapped objects as they were observed on-site.

The outcomes of the case study applications and data analysis provide an impression of the extent and nature of public spaces in the case study areas. Presented in the form of a map (see Figure 1), inspired by the cartographic design of the historic Nolli map, it shows where and what type of space is publicly accessible. For instance, more than half of the inaccessible space is traffic area. These inaccessible spaces can be considered as opportunities to increase and create attractive public space. In addition to the map, a quantitative comparison of areas, for example visualized through a bar chart, offers insights to the ratio of publicly accessible and inaccessible areas. These values can be compared between different neighbourhoods and the result can serve as an indicator and basis for identifying needs in urban planning.

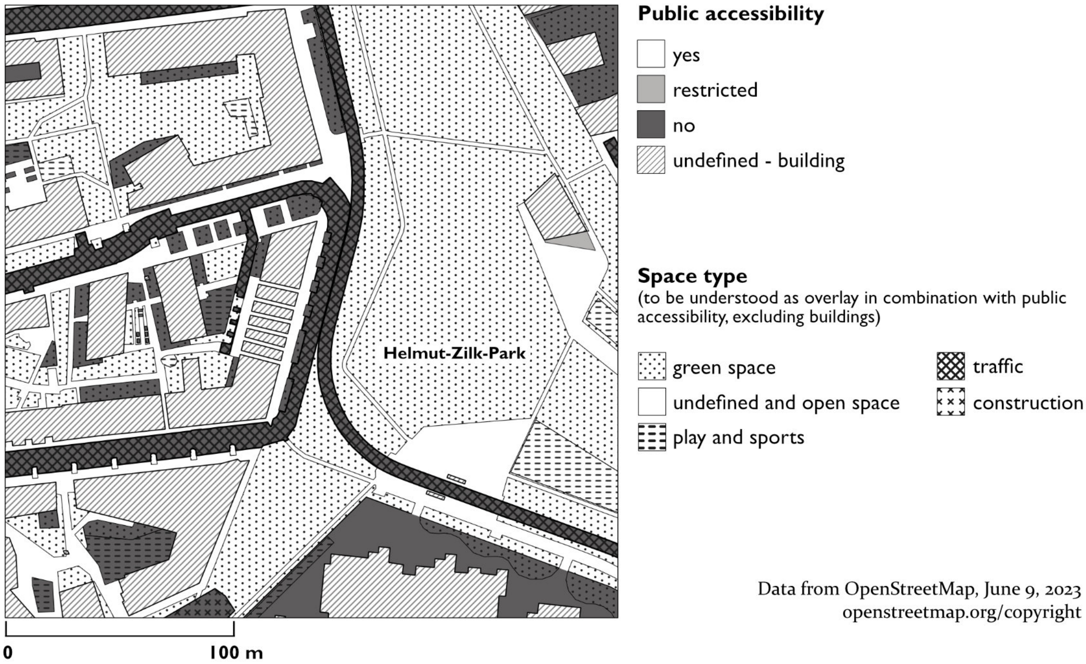

Figure 1. Map section of the case study Sonnwendviertel, Vienna, showing the public accessibility and space type in the area.

The case study applications not only offer valuable insights into public spaces within the selected areas but also provide an opportunity to reflect on the data analysis process and the reliability of the results. In particular, the importance of the on-site data collection has to be emphasized. In both case studies, the number of OSM elements in the areas increased by almost 50% during the on-site mapping phase. While it is possible that some edits may have originated from other OSM contributors, it is reasonable to assume that the majority of these new elements were added as part of this research project. These additions are crucial in achieving differentiated and, as validated through ground-truth checks, accurate results. Another interesting revelation is that most of the area in the resulting map had its public accessibility identified through the space type (level 3 of the analysis). Although this is the most generalized analysis level, we consider the assumptions to be reliable, because more specific information (like access permissions or fences) would have been added during on-site mapping and included on level 1 and 2 of the analysis.

Furthermore, the on-site mapping unveiled some qualitative aspects and limitations of the analysis. For example it became evident that public accessibility alone does not necessarily make a space truly public, as it may still be difficult to access or feel unwelcoming for individuals. Nevertheless, this analysis can be a foundation for deeper research in the realm of public spaces. Given its open-source code and the availability of the global OSM dataset, this framework can be applied to diverse neighbourhoods and locations. However, it is essential to bear in mind that the framework is developed with Central and Western European cities in mind. The variables and tags used in the analysis may need to be adapted and it should be noted that the underlying understanding of public space is not easily transferable to fundamentally different cultural and spatial contexts. On a larger scale, the examination of extensive areas or entire cities would provide valuable insights, but the developed framework currently faces performance limitations and gaps of the relevant information in the OSM dataset, making it less suitable for extensive application in its current state. Subsequent research should delve into how the OSM dataset can be further leveraged and which other open datasets might be suitable to enhance the analysis. The work at hand can be the base for research in this direction and enrich the social and political debate about the distribution of urban space. It also highlights the potential of OSM data for social study of spatial issues. Furthermore, it demonstrates the adaptability of a cartographic classic to contemporary circumstances and the opportunities afforded by GIS and open data. Through semi-automated data processing, the framework extends the previous approaches to create a modern-day Nolli map.

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