# Graffiti Exploration via Interactive Web Maps

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**Abstract**
This article explores the intersection of graffiti, street art, and cartography through web-based maps. Graffiti and street art pose challenges in representing their diverse and short-lived nature on maps. The ephemeral and location-specific characteristics of graffiti and street art are discussed, emphasising their connection to their original urban landscapes. Maps are proposed as vital tools for preserving their context. Current graffiti web maps are evaluated, revealing common (interactive) functionalities and limitations. The article advocates for user-friendly and advanced web maps. The nuanced representation of graffiti on maps, considering factors like size, shape, and orientation, is discussed. The development of a web map prototype showcasing graffiti along Vienna's Danube Canal is detailed. The prototype utilises adaptive symbols to optimally represent graffiti across various map scales. Additionally, the option to view the map in a 3D mode is integrated to provide a more realistic view of the vertical dimensions of graffiti and their surroundings. The usability of the web map prototype is evaluated, identifying areas for improvement, especially in the visibility of graffiti features. In summary, the article underscores the unique character of graffiti and street art as map features linked to urban environments. It emphasises the potential of web maps but calls for technological and usability enhancements, contributing to a deeper understanding by preserving these art forms within their (spatial) contexts.

**Keywords**
3D mapping; Feature generalisation; Graffiti; Interactivity; Street art; Web mapping

## 1. Introduction

Nowadays, many consider graffiti and street art cultural heritage worth preserving (Bonadio, 2022; Merrill, 2015). There has been an increase in public and research interest in these artistic practices and creations, especially with the more recent rise of street art (de la Iglesia, 2015; DeTurk, 2015). While there are distinctions between graffiti, often centred on textual-based content, and the genre of street art, known for its diverse and image-based forms, this article, in alignment with the recommendation of some scholars (Avramidis & Tsilimpounidi, 2017; Parker & Khanyile, 2022), employs the terms interchangeably for simplicity.

Graffiti and street art creations are inherently ephemeral, relying on various media for preservation and dissemination. Although these works maintain a strong connection to their physical locations and continue to be produced in the physical world, their digital representations are increasingly shared online. Individuals, including graffiti artists themselves, are embracing the digital realm as an extension of the milieu for these creations. The digital realm, including its social media platforms, is witnessing increasing adoption and utilisation by graffiti and street art practitioners to gain more visibility and broaden the reach of their artistic work (Honig & MacDowall, 2017). Without such digital dissemination, as these creations are destined to be concealed, removed, or decay, their visibility would remain limited to fortunate passersby, who might still overlook them.

One of the many digital avenues for sharing and disseminating these artworks is through web maps. While there has been considerable research and attention focused on the spatial analysis of graffiti (Bartzokas-Tsiompras & Konstantinidou, 2023; Tokuda et al., 2021), exploring the intersection between the domains of street art and cartography is still a relatively unexplored area. Despite the existence of numerous (web) maps and archives dedicated to graffiti, the subject has yet to be formally addressed from a cartographic perspective, which is precisely the aim of this article as it strives to take initial steps into this direction.

This study aims to achieve several objectives. First, it seeks to identify the current state of graffiti web maps, analysing common features and patterns. The next aim is to conceptualise more effective and realistic graffiti symbolisations for individual and collective graffiti occurrences. The creation of such cartographic symbols relies on access to complex graffiti geo-data (shapes) and is guided by theoretical considerations of the spatial characteristics of graffiti. The symbols, adaptive to zoom-level or map scale, are incorporated into a web map prototype. The development of this prototype demonstrates interactive features beyond most current graffiti-dedicated web maps. It introduces a 3D map mode, enabling users to delve into the exploration of graffiti creations along the Danube Canal (Donaukanal) area in Vienna, Austria.

Finally, the article will present the evaluation of the prototype in terms of user experience and usability through a qualitative user study. The goal is to identify potential usability issues and areas for improvement. These efforts are expected to contribute to more effective map-based dissemination and produce potential insights into the phenomenon of graffiti and street art.

## 2. Graffiti's Dynamic Context: Spatial and Temporal Dimensions

Graffiti and street art practices produce highly contextual works that incorporate temporal and spatial aspects. These forms of artistic expression can be considered among the most spatial due to their fundamental premise: the entire urban landscape as an intricate, boundless canvas open to creative visual art-making, transcending the spatial confinements of conventional art galleries (Austin, 2010).

Each piece of graffiti is site-specific in its meaning to some degree (Bengtsen, 2013). Its chosen location becomes an integral component of its identity (Ferrell & Weide, 2010). For illustration, the content and theme of graffiti often draw inspiration from their immediate environment, including urban infrastructure, nature and other graffiti (Wild et al., 2023). Graffiti pieces can reference their surroundings and engage in a creative dialogue with them (see Figure 1). They are scaled according to the space available on their given wall or surface section. Some are tailored in a way so the usually two-dimensional surfaces they cover seem to cleverly interact with or incorporate their three-dimensional surroundings. This dialogue between neighbouring graffiti and their environment leads some to view graffiti walls as 'narrative space' (Carver, 2018; Sennett, 1990). In fact, a dual and reciprocal relationship exists between graffiti and their urban environment. Once created, graffiti become part of the environment, influencing and reshaping it in return (Chmielewska, 2007; Ermolaeva, 2014).

Most graffiti walls undergo frequent repainting, a result of the dynamic interplay between various writers who compete and collaborate on the shared public canvas. That applies to the Donaukanal area in particular, where individual works are less likely to persist for years but instead have a transient existence, often lasting for weeks or even only for mere hours.

The average time it takes for graffiti to get covered by new graffiti varies greatly from wall to wall and depends on numerous factors, including weather conditions. A compelling case study to consider is MacDowall's (2016) investigation into graffiti's temporalities. Based on near-daily visits, he tracked six walls at a fenced suburban site in Melbourne, Australia, for over 600 days starting in mid-2014. His data show a total of 186 pieces that were painted by 73 artists, resulting in a 20-day average time of visibility for each graffito. These results are interesting and help to demonstrate the short-lived nature of graffiti. However, to use the words of the study's author, "due to the many

**Figure 1.** Contextual graffiti. Left: Nature-themed graffito at a grassy area in Gdańsk, Poland, in 2019. Right: Pirate treasure map theme near a harbour in Szczecin, Poland, in 2019. Photos by Nathan Winder.

complex factors through which graffiti is produced, the results can't be extrapolated to other sites nor can a causal link be demonstrated" (MacDowall, 2016, p. 57).

As a highly contextual art form, losing connection to their spatio-temporal context is detrimental to graffiti's meaningfulness. When preserving and presenting graffiti data, associated geospatial information is of great importance and should not be neglected as "each instance of graffiti writing comes to life at a particular location–and within a network of locations that, taken as a whole, chart contours of status and meaning within the world of urban graffiti" (Ferrell & Weide, 2010, p. 50).

**3. The Map in Preserving Spatial (and Temporal) Contexts**

To visualise graffiti in their spatial context, revealing such literal contours of status and meaning within a city, one may use the established medium of a map. A map allows for a clear and intuitive way to present spatial realities and their mutual relationships. Since they excel at illustrating how graffiti and their surrounding environment spatially coexist, maps are arguably the most apt solution for precisely conveying graffiti data within its immediate spatial context. Utilising maps as a medium for presenting graffiti data inherently counters the risk of spatial decontextualisation (Bengtsen, 2019), thus preserving the essential locational information of graffiti. Preserving this attribute of graffiti contributes to obtaining a more comprehensive understanding of street art and graffiti, encompassing their content, messages, and the extractable cultural and social insights they offer.

It is vital to acknowledge that the attempt to uncover the influences between graffiti and their spatial environment solely through the medium of a map is somewhat limited. While a map alone can provide insights to some extent, it is important to recognise that, by its very nature, it is an abstract model of spatial realities (Lapaine et al., 2021). Consequently, it can only show fractions of the multifaceted relationship between graffiti and the environment. However, a map is easily merged and enriched by other media. With the steady emergence of increasingly user-friendly and more functional multimedia web mapping technologies, the notion of abstraction being the ultimate goal in cartography seems outdated to some (Peterson, 2007). Instead, “multimedia cartography is based on the compelling notion that combining maps with other media (text, pictures, video, etc.) will lead to more realistic representations of the world” (Peterson, 2007, p. 64). Web maps can ground graffiti data spatially while complimenting it with information in various media formats. This makes multimedia graffiti web maps ideal for presenting contextual-intact graffiti and letting users interact with and gain a varied nuanced understanding of them. As remarked by Cartwright and Peterson: “People want to ‘go into’ the map, both spatially and conceptually. They want to explore at a deeper level” (Cartwright & Peterson, 2007, p. 2). This aspiration has transitioned from a mere desire to an actual reality. A web map may facilitate user engagement with graffiti through immersive new media experiences such as augmented reality (for instance, https://streetartifacts.xyz).

An intriguing example of the compatibility between graffiti and cartography is given by Hale and Anderson (2020) when showcasing notable graffiti works they have documented. One such piece depicts a profile portrait of a man with an open mouth, from which a speech bubble emerges containing two lines of numbers: ‘55.870056 – 5.306956’, representing the latitude and longitude coordinates of its location in Pollphail, Scotland (see Figure 2). When these coordinates are input into online mapping tools, they direct the viewer to the central recreation block of the village. Through digital media, the work quite literally puts Pollphail on the map, allowing remote viewers to discover its location while viewing a photograph of the graffito. In doing so, the artist initiated the documentation process by geo-referencing the work for future archival purposes, prompting contemplation about the role of digital archiving and mapping in the artistic lifecycle. As the village has since been demolished (Galloway, 2022) traces of the artwork or clues on its location may have vanished in the absence of this specific documentation approach.

#### 4. Current State of Graffiti Web Maps Found Online

There are several web-based maps accessible online that are dedicated to graffiti with the goal of engaging audiences in interactive exploration. These web maps show where street artworks are located within different urban areas and facilitate the exploration of their attributes through


**Figure 2.** Left: A photograph of a graffito in Pollphail, Scotland, incorporating geographical coordinates of its location into the artwork. Photo by Wikipedia user “Alexgchale”. Link to the license: https://creativecommons.org/licenses/by-sa/4.0/deed.en. Right: A map showing the former location of Pollphail, with a marker placed at the coordinates displayed in the artwork, effectively geo-locating itself. Basemap provided by OpenStreetMap.

additional integrated multimedia content and descriptions. Nevertheless, the majority of these maps do not fully exhaust the technological capabilities offered by modern web mapping technologies, nor do they prioritise cartographic practices like feature-targeted generalisation for optimal graffiti representations across scales.

The eleven compiled web maps dedicated to graffiti and street art that were identified (see Table 1) show remarkable similarities, with some of them sharing common software technologies and libraries (e.g., Google My Maps), resulting in almost identical user experiences. Most web maps serve as platforms for users to explore and engage with street art on their own terms.

Across the board, these web maps provide users with a consistent set of basic functions to interact with the map and its graffiti features. These functions include zooming, panning, and retrieving information, which are listed among the interactive work operator primitives identified by Roth (2013). When users interact with features on these maps, such as clicking or hovering over them, individual popup boxes or sidebars appear, providing details on specific graffiti, such as photos, textual descriptions, artist pseudonyms, street addresses, and more. Most web maps also offer links allowing users to retrieve additional information and media related to the specific graffiti. Beyond these shared basic functionalities, some web maps facilitate users to search for a particular location or map feature of interest or to filter the map content. However, beyond these functions, the range of interactive options remains relatively limited. None of the maps introduces 3D capabilities or allows users to reproject the map in other ways.

Concerning basemaps, all employ responsive web tiles to ensure seamless user experiences and adjust the basemap's level of detail according to the map scale. Dynamic clustering is a widely utilised technique among these web maps, mainly due to the volume of data represented by map features. Most maps include collective features, which might not be due to the presence of actual and nearly impossible-to-map graffiti hotspots, but rather attributed to limitations in the spatial accuracy of the underlying data.

Regarding the level of detail, they typically provide spatial accuracy of graffiti at the level of a single coordinate pair, omitting any finer-grained spatial details indicating the actual shape and extent of an individual graffito. Also, temporal information concerning the visibility of graffiti is often lacking.

**5. Graffiti: A Nuanced Primary (Web) Map Feature**

Graffiti is a highly diverse and variable form of expression which presents unique challenges regarding cartographic representation. Finding a simple yet effective visual representation that accurately conveys the diverse graffiti and street art phenomenon can be challenging.

One of the primary attributes to consider, the size of these artworks, can vary drastically. It is influenced by several factors, including the artist's intention, available space, and the level of risk associated with the act of creation (Ferrell & Weide, 2010).

Over time, graffiti culture has given rise to numerous types or categories of graffiti. These types are, in part, distinguished based on their style, intricacy, location, and size (Tokuda et al., 2021). These categories exhibit general patterns, with certain graffiti types adhering to specific scales. However, these patterns are not rigid rules, as graffiti frequently deviate from the conventional size norms associated with their type.

As an exceptional case illustrating the variability in graffiti size, consider MOMO's famous Manhattan tag (Riggle, 2010). In 2006, street artist MOMO embarked on an ambitious artistic venture that left a mark, arguably the largest tag ever created, on New York City's urban canvas. The artist tagged the imprint of his name 'MOMO' across the width of New York City with a thin orange line of paint. The line measured almost 13 km in length and connected West Village to East River Park. This extraordinary creation defies conventional artistic dimensions, challenging one's capacity for visual comprehension. Interestingly, the best-suited medium for grasping the artwork in its entirety is via polyline geometry on a map (see Figure 3). MOMO's creation operates on both minuscule and monumental scales, leading some to regard it as a form of cartographic self-expression (Schacter, 2013).

| Name of Web Map | Area | Number of graffiti map symbols | Link |
|---|---|---|---|
| Atlanta Street Art Map by streetartmap.org | Atlanta, USA | 1274 | https://streetartmap.org/atlanta-street-art-maps/all-neighborhoods-street-art-mural-map |
| George Floyd & Anti-Racist Street Art Map by Urban Art Mapping | Worldwide (mostly USA) | 2942 | https://georgefloydstreetart.omeka.net/geolocation/map/browse |
| Graffiti Map Vienna by SPRAYCITY | Vienna, Austria | 2786 | https://spraycity.at/map |
| Los Angeles Map by Street Art Cities | Los Angeles, USA | 2246 | https://streetartcities.com/cities/losangeles |
| Map by street artifacts project | Portland and New York City, USA; Karachi, Pakistan | 213 | https://streetartifacts.xyz |
| Mural Map - Open Urban Art Museum Mannheim by Stadt.Wand.Kunst | Mannheim, Germany | 38 | https://www.stadt-wand-kunst.de/mural-map |
| Street Art Map Berlin by Vagabundler | Berlin, Germany | 1911 | https://vagabundler.com/germany/streetart-map-berlin |
| Turin map by Arte per strada Torino | Turin, Italy, and its surrounding towns | Around 400 | https://www.arteperstradatorino.it/mappa_EN.html#12 |
| World Collection Map by Google Art Project: Street Art | Worldwide | Hundreds | https://streetart.withgoogle.com/en-gb/world-collection |
| World Map by Bombing Science | Worldwide | 1331 | https://www.bombingscience.com/graffiti-map |
| Worldwide Street Art, Graffiti & Urbex Map by urbanpresents | Worldwide (mostly Germany and Belgium) | 227 | https://www.urbanpresents.net/en/map |

**Table 1.** Overview of the web maps dedicated to graffiti and street art that were identified and considered in the evaluation. All were accessed on 7 September 2023.

Shape is another variable aspect of graffiti that has mapping implications. As an art form unrestrained by the dimensions of regular canvases, graffiti often exhibits irregular shapes, devoid of fixed aspect ratios.

The variability is further heightened by the orientation in space. Graffiti predominantly extend along vertical surfaces, giving them a slim appearance when viewed from above. However, in less frequent instances, graffiti conform to a more horizontal plane when covering nearly level surfaces. Examples include graffiti applied directly onto roads or sidewalks, flat roofs, basketball courts, skateparks, or the upper sides of urban infrastructure elements. This diversity in shape and orientation can complicate the process of mapping graffiti effectively. In contrast to more old-school graffiti, some street art comes in the form of constructs exhibiting a three-dimensional structure and depth, such as sculptures, statues, or installations. This further underscores the need for thoughtful considerations when designing comprehensive cartographic representation for all forms of street art encountered within specific areas.

The inhomogeneous distribution of graffiti, marked by areas of intense spatial density within urban environments, poses further challenges. For instance, a single wall may be densely covered with hundreds of tags, creating a graffiti hotspot. Conversely, other city areas might display sporadic occurrences of larger murals or isolated tags. When attempting to delineate each individual graffito as a distinct map feature, these graffiti hotspots become even more prominent, further complicating the task of mapping graffiti due to the limited map space.

The decision to consider each individual mark, graffito, or complete wall a single feature on a map can significantly impact the level of detail and accuracy in graffiti mapping.

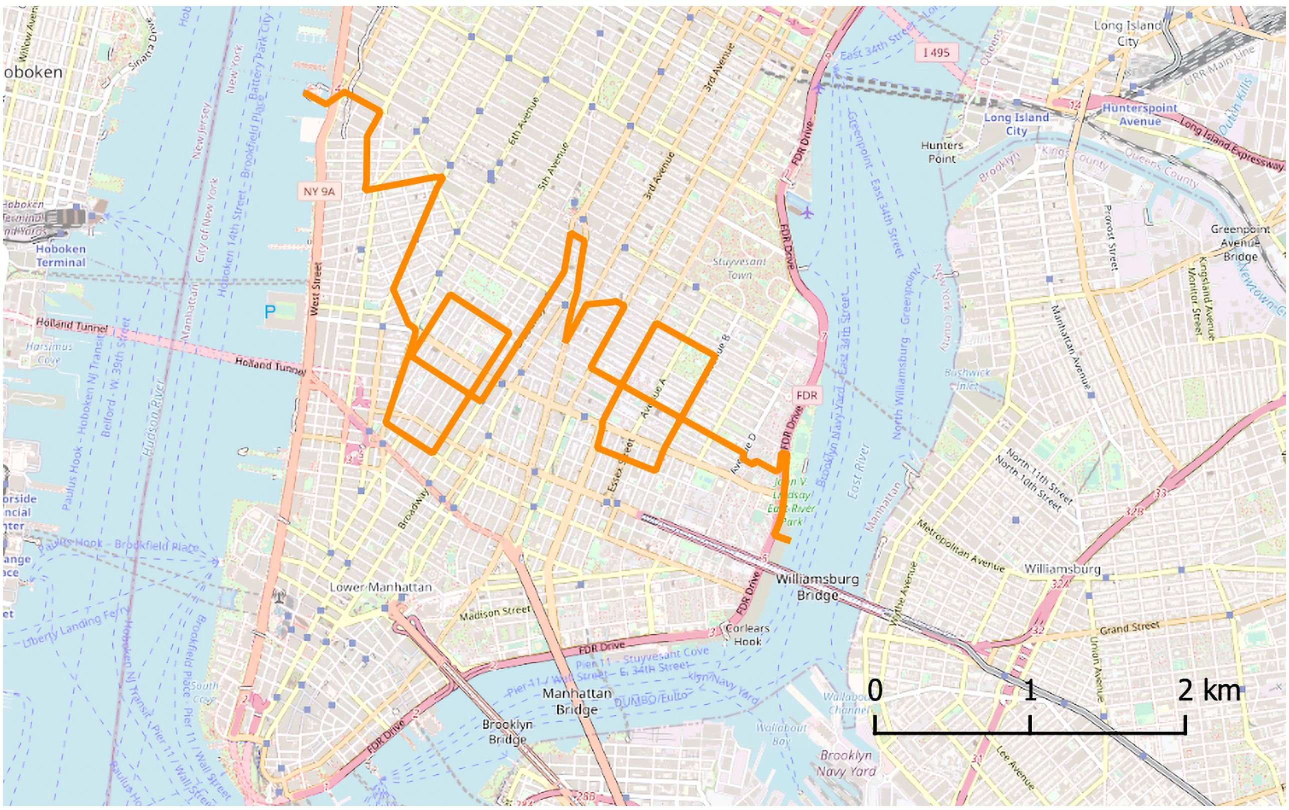


**Figure 3.** Possibly the longest single graffito: MOMO's Manhattan tag visualised on a map in orange. Map by the author based on the map found in The World Atlas of Street Art and Graffiti (Schacter, 2013). Basemap by OpenStreetMap.

Notably, while defining the extent of an individual graffito becomes a crucial task in accurately representing the distribution of graffiti on maps, the boundaries between individual graffiti artworks (i.e., where one work ends, and another begins) can be unclear and ambiguous. Capturing individual graffiti as features on a map can lead to information overload, visually cluttered maps, and reduced readability. On the other hand, diminishing the variability of graffiti can lead to oversimplification and loss of valuable information.

In densely graffitied areas, an alternative approach may involve treating an entire area, graffiti-covered wall, building, or a large graffito composition as a collective feature. To achieve this, the cartographic generalisation operator referred to as 'merge', 'dissolve' or 'amalgamating', first defined by Imhof (1936), may be used. This approach simplifies the map by representing graffiti as concentrated clusters or continuous stretches, reducing visual clutter while still acknowledging their presence.

Along those lines, dynamic or adaptive clustering represents a commonly used variation of collective map features in web mapping to address visual clutter, the latter often being described as simply "too many markers" (Fürhoff, 2019, p. 1). With this method, the number of individual features clustered together depends on the map's current zoom-level and the distance between these features. As the user zooms in to decrease the map scale, a growing number of clusters break down into sub-clusters, eventually revealing the individual features once the map is zoomed in sufficiently.

Ultimately, striking the right balance between providing intricate details of individual graffiti features and utilising generalisation techniques is crucial in creating effective and informative cartographic products. Given the inherent variability of graffiti and street art in size, shape, and orientation, cartographers face the challenge of effectively abstracting and displaying them on maps.

The combination of all these aspects indicates that there can be no universally correct approach to represent graffiti cartographically; instead, the choice depends on factors such as the available data, the scale, and the conditions specific to the area of interest being mapped. Interactive web maps, which allow users to adjust zoom levels dynamically, hold the potential to provide different visual representations of graffiti that automatically adapt as users zoom in or out. This adaptability may involve transitioning between point, line, and polygon symbology, provided that graffiti data of necessary quality are available.

## 6. Development of the Web Map Prototype

The purpose of the web map prototype is to enable users to visualise, explore, and query graffiti along Vienna's Danube Canal (Donaukanal). In that sense, this prototype aligns with the goals established by project INDIGO (IN-ventory and DI-sseminate G-raffiti along the d-O-naukanal), an academic graffiti project launched in September 2021 through funding from the Heritage Science Austria programme of the Austrian Academy of Sciences. INDIGO wanted to push the boundaries in inventorying, disseminating and understanding extensive graffiti-scapes like the one found along Vienna's Danube Canal. INDIGO aimed to create its own graffiti exploration platform using a specific technology stack (see Schlegel et al. in this volume). However, this did not exclude others from investigating alternative ways to visualise and explore INDIGO's data. In this light, the present web map prototype must be seen. Rather than being an official project deliverable, this prototype resulted from the author's master thesis.

The prototype in its finalised state (see Figure 4) as it was presented to the user study participants (see Section 7) is accessible via GitHub at: https://oacbaumann.github.io/graffiti_map_UserStudy. The web map prototype was developed using the open-source JavaScript library MapLibre GL JS, as it offers lightweight 3D mapping capabilities. Language analysis for its GitHub repository indicates that it comprises 82 % JavaScript, 9 % HTML, and 9 % CSS code.

### 6.1 Data Sources

For integration into the web map prototype, project INDIGO provided a sample graffiti dataset in the form of 97 orthorectified image files in the PNG format and 97 corresponding individual geo-referenced high-detail 3D polygons in ESRI shapefile format. These polygons accurately

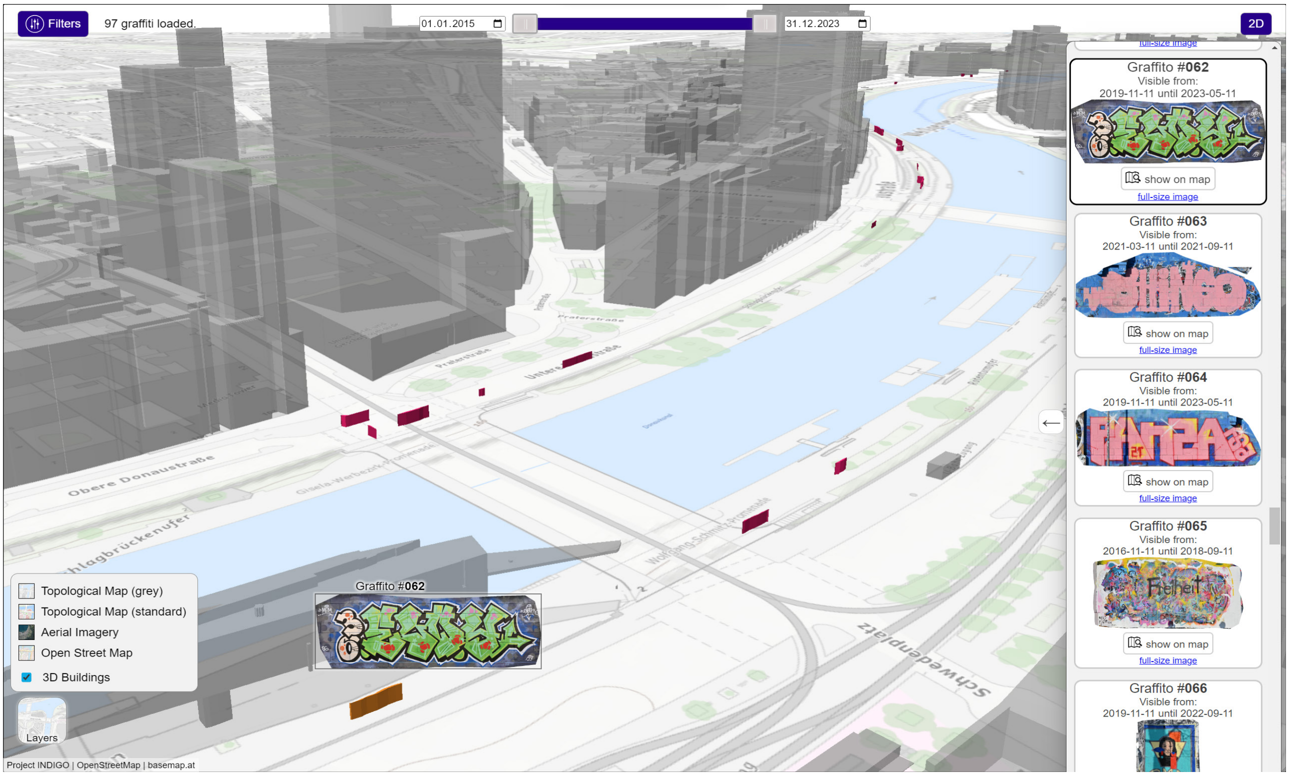


**Figure 4.** The finalised web map prototype's interface (3D mode) allows for immersive graffiti exploration along Vienna's Donaukanal. Elements of the graphical user interface include a box containing filter options, a time slider, a map menu, and a sidebar listing all currently visible graffiti.

delineate the spatial dimensions of each graffiti border. A detailed explanation of the methodology used for deriving the polygons and the orthorectified graffiti images can be found in Wild et al. (2022).

The default raster tile map that acts as the base of the prototype is requested from https://basemap.at. The choice fell on this basemap as it exhibits the best alignment with the graffiti data, placing them on walls in a manner that appears highly plausible and accurate where observable.
Additional building data are sourced from Vienna's city office department 41 (Magistratsabteilung 41) as Open Government Data. This dataset offers a notably high level of detail and incorporates attributes such as absolute elevation and base markings.

6.2 2D-Map-Mode-Adaptive Graffiti Symbology

In the web map prototype's 2D mode, adaptive symbols are used to effectively represent graffiti across different zoom levels or map scales (see Figure 5). When zoomed in closely, individual graffiti are represented by the original polygon geometries. As users zoom out to smaller scales (i.e., wider views), more simple geometric representations are active, such as polylines or dynamic point clusters, to maintain optimal visual clarity. The dynamic clusters representing graffiti in smaller scales are placed at the centroid coordinates of the original polygons. The polyline geometries active in the medium to close map scale range are derived from the original polygons by retaining only the two most distant vertices of each polygon and connecting them with a line. Upon conducting a personal visual assessment and comparison of the 97 original 2D graffiti polygons and their corresponding simplified line equivalents in a top-down view at 1:250 scale, the findings indicate that the shape of 87 of the graffiti is accurately conveyed by the line geometry. However, in the case of 10 graffiti features, the representation is less fitting due to the surfaces they adorn not being flat or potential issues with the original data. This equates to nearly 90 % of the graffiti being effectively represented in terms of their approximate shape and length. Considering that the original dataset provided by project INDIGO was derived from their experiment in which "100 graffiti were randomly selected from all graffiti documented between November and December 2021," this 90 % level of satisfactory cartographic representation via line features in the close to medium scale range provides an indication of the potential accuracy for the remaining graffiti found in the Donaukanal area that project INDIGO covered.

### 6.3 3D-Map-Mode

An effective solution for displaying the predominantly vertical extending phenomenon of graffiti emerges with the implementation of a 3D map mode, offering total control for interactive camera rotation of 360°. This reveals to map users what's directly above and below any given graffiti features, thereby enabling a comprehensive representation of complete graffiti-covered walls.

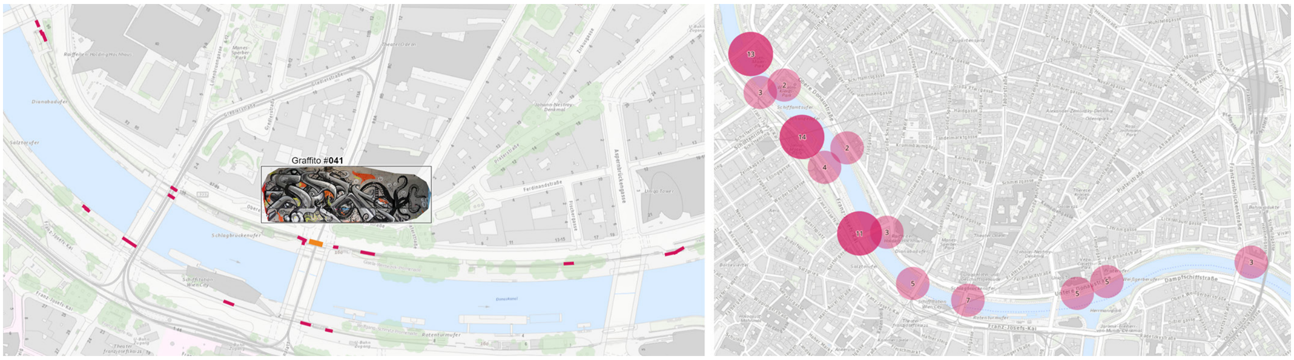


**Figure 5.** Partial screenshots of the web map prototype in 2D mode showing the changing representation style based on zoom level. Left: Graffiti represented as line features. Right: Dynamic graffiti clusters.

The three-dimensional graffiti features are created by extruding the flat 2D polygons. From a technical standpoint, this is accomplished by processing each vertex of the original 3D polygon and determining both the overall maximum and minimum height values. These values are subsequently used to establish the elevation above ground and height for the entire, horizontally oriented polygon forming a solid 3D feature. While this solution may not reflect perfect accuracy, it offers a more simplified approach. It contributes to creating a 3D web map that delivers fast and reliable performance, making it a more lightweight and practical choice, especially when dealing with a relatively small geographic area. In contrast, other web mapping libraries are based on entire virtual 3D globes.

The additional 3D building map features visible in this mode serve a multifaceted role: first, they offer orientation; then, they complement the graffiti, providing context to potentially unveil their interactions with one another; moreover, they guide the user's focus toward the Donaukanal, where graffiti are located; finally, they provide the area with a more pronounced three-dimensional character by hinting at the rising heights around the canal, preventing the graffiti from appearing isolated in space.

### 6.4 Graphical User Interface and Interactive Functionalities

The interactive prototype allows the use of the following cartographic interaction operations as defined by Roth (2013): pan, zoom, retrieve, filter, reproject, resymbolise and search.

Panning and zooming functionalities are readily available by default, courtesy of the web mapping library. They can be accessed through standard map controls: left-clicking and dragging on the basemap for panning, and using scroll inputs for zooming.

To retrieve information about the map features, users can hover over graffiti features, revealing individual graffiti popup boxes, which also triggers automatic adjustment of the sidebar to display selected graffiti fields containing additional information. For 3D building features, information is accessed by left-clicking the buildings, which opens the building popup boxes.

Filtering options are accessible through the main filters at the top-left of the interface, encompassing both spatial and semantic filter choices, as well as the time range slider for temporal filtering.

Map reprojection is possible by changing map modes from 2D to 3D or vice versa, and by rotating the 3D map via holding right-click and dragging the cursor.

Graffiti feature resymbolisation can be achieved by changing map modes or adjusting the zoom level in the 2D mode, causing symbolic representations to change.

'Search' in the context of cartographic interaction operators is defined as "interactions that identify a particular location or map feature of interest. [...] Search directly enters the map to locate a feature of interest that is already known" (Roth, 2013, p. 2363). This way of interaction is available in the prototype through clicking the 'show on map' buttons within the sidebar, which triggers the virtual camera to move and face the selected graffito.

**7. Evaluation of the Web Map Prototype**

Since the web map prototype is to be user-friendly and practical, it is essential to assess its usability and gather insights into the user experience. To evaluate the completed web map prototype, a qualitative user study involving six participants was carried out. These individuals were observed during their interaction with the prototype and provided feedback to questions in a subsequent interview setting. As a combination of several methods is expected to provide the best results (Dicicco-Bloom & Crabtree, 2006; van Elzakker et al., 2008), the user study combined three usability testing methods applicable to maps: observation of interaction including performance measurements (Edsall, 2003), thinking aloud (Roth & Harrower, 2008), and semi-structured interviews (Slocum et al., 2004).

Besides evaluating the prototype's graphical user interface for usability, the user study served as the initial external evaluation step within the iterative user-centred design cycle (Abras et al., 2004; Roth et al., 2015), potentially guiding future enhancement and development efforts.

Although the number of study participants was relatively small, they can certainly unearth most usability issues. Nielsen (1994), for instance, based on two studies employing the thinking aloud method for user interface testing, suggested that as few as five test subjects can uncover and identify 77 % – 85 % of usability problems.

The design of the user studies was such that after initial familiarisation with the prototype and its interface, participants were given tasks to complete, such as: "Describe where graffiti with political content were located in the year 2021!". These tasks required participants to utilise the web map as a tool, using its filtering options to pinpoint specific graffiti features on the map. Subsequently, a post-use interview was conducted where participants could share their thoughts on their user experience, including any usability issues they encountered.

The user study results showed that all participants successfully completed nearly all tasks, with an average completion time of 2-3 minutes per task. Both the 2D and 3D map modes were used by participants, which may indicate that providing this choice of mode seems wise, as most users found value in both.

The findings also highlighted certain trends in usability issues, with the visual prominence of graffiti map features emerging as a prominent concern. None of the participants' initial interactions or points of focus were on the graffiti features, even when excluding the typical initial actions of testing the basic map controls and zooming out to explore the map's maximum extent. In fact, identifying the graffiti features, which are the primary focus of the map, proved to be quite challenging for participants. This difficulty stemmed

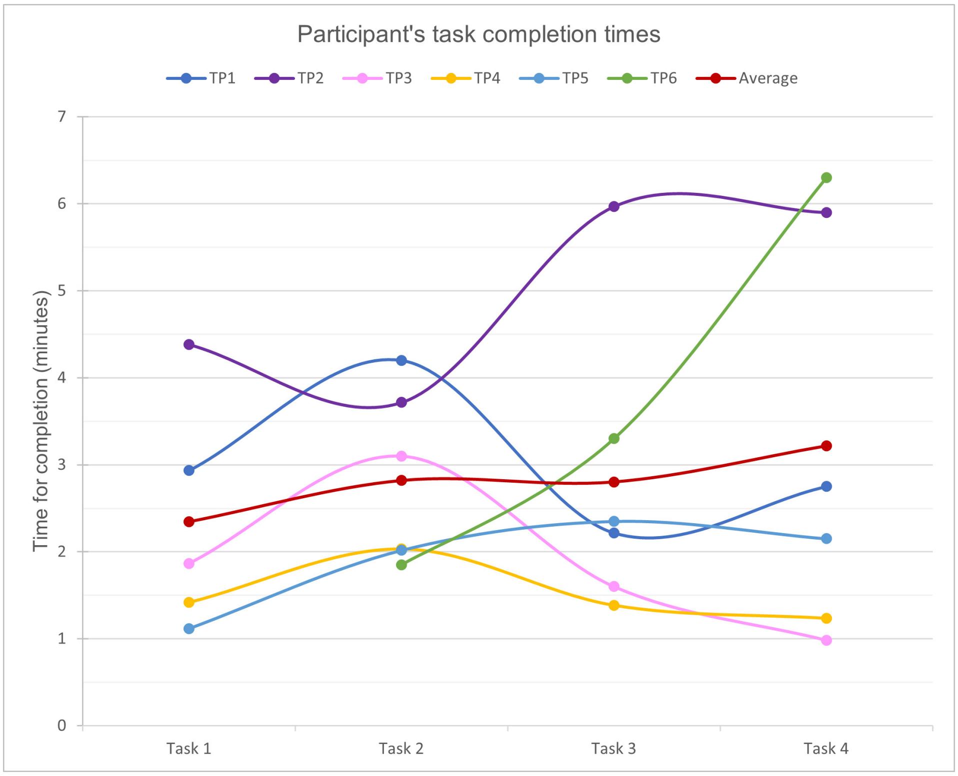


**Figure 6.** Line chart showing participant's task completion times and the resulting average times of completion.

from the graffiti features lacking sufficient visual prominence, especially in 3D mode, compared to the building features.

The observation and thinking-aloud methods revealed insights into other common usability issues encountered by participants. These issues are expected to be indicative of problems shared by a broader user base. The recurring patterns observed in at least two participants include, from most prevalent to less prevalent: difficulties with using the map controls in the 3D map mode, challenges in locating specific graffiti features after applying filters, issues with activating the display of the right sidebar, difficulties in finding the basemap menu, and challenges in hovering over thin graffiti map features.

## 8. Conclusion

Maps offer a suitable medium for showcasing graffiti especially when complemented by other media. Graffiti make for rather complex map features, primarily due to their inherent variability in size, shape, orientation, and their propensity to form dense clusters.

Graffiti's inseparable connection with their urban environments, upon which they depend for context and understanding, sets them apart as unique map features. This distinguishes them from other phenomena like billboards, which are also colourful, visible to passersby, and typically exhibit a predominantly flat and vertical spatial character.
Existing web maps dedicated to graffiti, which are available online, have the potential to be enhanced from a technological standpoint to offer a more immersive and interactive user experience. The developed web map prototype shows how current graffiti web maps could benefit from adaptive graffiti symbolisation and additional interactive functionalities, including a 3D map mode option. Different scale-dependent symbolisation styles can be implemented to accommodate the inherent variability of graffiti, as demonstrated in the prototype's 2D mode. However, it is important to emphasise

that access to highly detailed graffiti data is a prerequisite for implementing such adaptable symbology.

Moreover, despite some usability issues, the prototype successfully enabled all user study participants to answer basic spatial, temporal, and semantic questions related to graffiti. These participants could independently complete nearly all tasks they were given by applying filters to graffiti map features and adjusting the map view. It was evident that one of the foremost issues, among others, to be addressed in future design iterations is the increase in the visual prominence of graffiti features on the map. Identifying them as such proved to be a significant challenge, and improving their visibility is a priority.

**Conflict of Interest**

The author declares no conflict of interest.

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