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grARffiti: The Reconstruction and Deployment of Augmented Reality (AR) Graffiti

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Abstract: Graffiti relies on social instrumentation for its creation on spatial structures. It is questioned whether different mechanisms exist to transfer social and spatial hierarchies under a new model for better engagement, management, and governance. This research aims to replace physical graffiti using augmented reality (AR) in smartphones. Contact-free AR graffiti starts with the creation of 3D graffiti; this is followed by an AR cloud platform upload, quick response (QR) code access, and site deployment, leading to the secondary reconstruction of a field scene using smartphone screenshots. The working structure was created based on the first 3D reconstruction of graffiti details as AR models and second 3D reconstruction of field graffiti on different backgrounds using a photogrammetry method. The 3D graffiti can be geotagged as a personal map and 3D printed for collections. This culture-engaged AR creates a two-way method of interacting with spatial structures where the result is collected as a self-governed form of social media. The reinterpreted context is represented by a virtual 3D sticker or symbolized name card shared on the cloud. The hidden or social hierarchy was reinterpreted by a sense of ritual without altering any space. The application of digital stickers in AR redefines the spatial order, typology, and governance of graffiti.

Keywords: graffiti; AR; urban fabric; governance; generative AI

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1. Introduction

Can graffiti enhance a space in the same way that an architect or architecture enhances urban fabric? Graffiti deployed on a surface is not much different from the designs made by architects. From intangible inspiration to a tangible graphic statement, an artist or a creator selects a theme, highlights social issues, collaborates resources, manages co-workers, chooses sites, plans access, makes a schedule, applies appropriate media, adjusts the layout, manages viewpoints, shares information with the community, collects responses, and avoids conflicts from governors or other artists. This series of tasks makes graffiti so unique and enjoyable, but also subjects it to the restrictions of physically presented processes and media in as-built 2D or 3D spaces.

It seems that either graffiti enhances a scene, or the urban fabric enlightens or facilitates the occurrence of graffiti (Figure 1). The significance of graffiti is a result of the marriage of statements with host spaces along a collection of urban fabrics. Graffiti used to be a one-way delivery-oriented message to receivers. It starts with the search for spaces suitable to deliver personal statements. The spaces or media are selected and judged based on whether they are effective for successful communication with future visitors.

1.1. Research Goal

Does graffiti change a space after a visit? This research aims to reconstruct physical graffiti in augmented reality (AR) with a smartphone. The goal is freedom of delivery without physical contact with a space, while also sharing the creations with everyone. In this way, graffiti does not have to always be created in the darkness or when no one is in sight, nor does it need to be maintained or governed.

Figure 1. Observations of graffiti (painters unknown, Harvard, Boston, 2011; Berkeley, San Francisco, 2004).

1.2. Related Studies

This interaction between urban spaces and deployed graphic statements involves the dialectic between unique spatial structures and the role of artists, visitors, and governors. On the one hand, graffiti is part of the context of social–spatial dialectic studies [1]. Visual and built environments have been reconfigured to communicate the transition away from conflict [2]. Since public spaces are not simply spaces for conflict but also for collective engagement [3], urban redevelopment can provide a platform and create opportunities for increasing the visibility of graffiti [4]. On the other hand, graffiti is considered a representation of informality in urbanization, arguing against politics and urban governance [5]. It is frequently connected to politics [6,7], since street art is a form of social, political, and cultural protest and critique [8]. Graffiti is also considered a critical social and spatial practice that challenges the cultural planning paradigm [9].

The esthetics of graffiti are a topic of discussion in the governance of urban landscapes [10]. Street art can have positive effects on the urban landscape as a part of cultural identity [11]. It is considered a management issue by many city governments, debated as an act of colonizing public spaces and of freedom of speech [12]. Both the USA [13] and local governments in Taiwan [14,15] have introduced regulations for graffiti [16–18]. Japan [19–23], Taiwan [24,25], and Hong Kong [26] have repeatedly made public comments on the topic. However, the cultural regeneration movement seems to provide an alternative to graffiti governance [11].

Public visibility is fleeting within urban environments [27]. Expressive subcultures such as graffiti often appear monolithic in their aim, esthetic, and action [28]. New means of self-expression have emerged: emojis and stickers. The former is a visual language system that uses digital technology for asynchronous communication [29,30] and has the potential to increase the clarity of cross-cultural communication [29]. The impact of stickers and emojis in enhancing emotional communication requires further research [31,32]

Graffiti is a form of tailored content that needs a virtual platform to be anticipated and promoted. Emojis and stickers are already supported by social platforms and e-commerce, and the use of graffiti should also be allowed in the future to provide feedback on an urban space without concerns around governance. Thus, generative artificial intelligence (AI) can be used as a low-effort entry point to create a new, virtual form of graffiti.

For this, augmented reality and CPGs should be combined to relate context to the role, interface, social behavior, or scenarios in well-defined measures. This requires a visual solution such as consumer packaged goods (CPGs) (including fast-moving consumer goods, or FMCGs) for successful and low-cost application to drive field promotion and increase e-commerce engagement [33,34]. Related benefits should include master data management, time to market, digital transformation, direct-to-consumer (D2C) commerce, supply chain optimization (resilience), and sustainability [35].

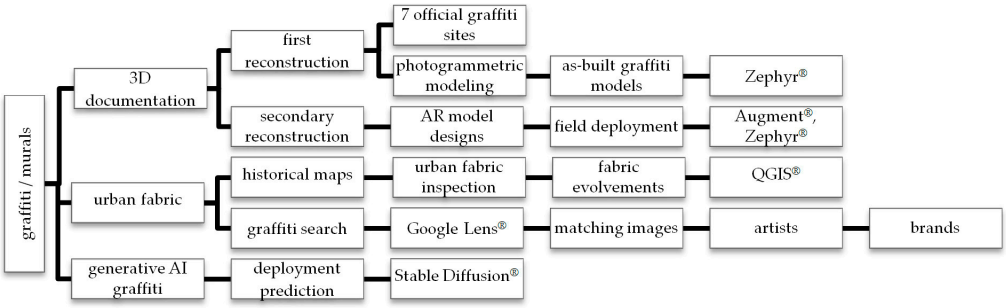
AR street art has been applied in a class [36], YouTube tutorial [37], art service [38], and art project [39], and there have been discussions integrating the transformation of the urban landscape [40]. Most of the applications are presentation- or interaction-oriented, without being documented as final 3D models afterward.

Other than screenshots obtained with a remote control and 2D screen annotation created with AR remote assistance [41], Augment® (v. 5.6.1+30711) uses first-person AR object interaction in the preferred 3D format and dimensions. The first 3D reconstruction of graffiti in a virtual space can be achieved through virtual reconstruction, i.e., structure from motion (SfM) photogrammetry [42–44]. With the solutions provided by existing tools and platforms, graffiti can become a first-person AR object that can be shared on the internet and distributed around the world.

Field graffiti applications should allow a fast and intuitive simulation of new compositions. In addition to 3D modeling and simulation [45], this method has been applied in research projects to explore the composition of cultural installations and heterogeneous landscape sites, or to AR through secondary reconstruction [46,47]. This novel approach was feasible for an application in which a former iconic cultural landscape was evaluated in relation to a new emerging design within the existing urban fabric, combining a scaled 3D physical model.

2. Materials and Methods

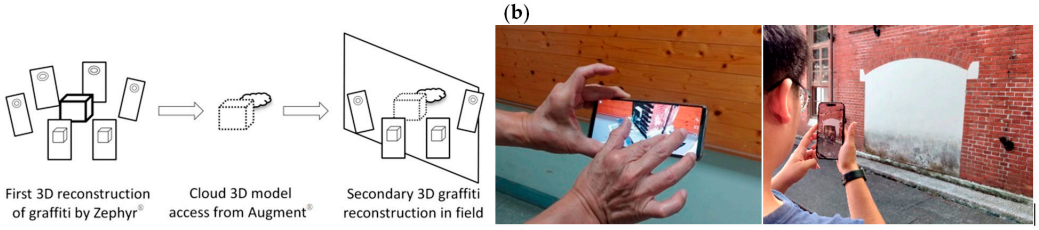
In this study, seven graffiti sites were investigated. This approach has three purposes, namely, providing a (1) survey of the evolving urban fabric; (2) creating a 3D documentation of graffiti in the field; and (3) reinterpreting the graffiti context using AR (Figure 2a), tools (Figure 2b), and processes (Figure 2c). The process presents an exploration of the spatial structure that is enhanced by graffiti, which is followed by personal, contact-free responses or engagement through the contribution of individuals' own creations, with potentially governance-free involvement.



(**a**)

	Tasks	Devices, software, app	Platforms	Notes
1	Images: still, videos	Sony® Xperia 1 II, iPhone® 15 pro	Smartphone	First and second reconstruction
2	Photogrammetry modeling	Zephyr® Lite (v. 7.529), Zephyr® (v. 7.531)	Notebook	First and second reconstruction
3	3D modeling, editing	Zephyr® (v. 7.531), Meshlab® (v. 1.3.3)	Notebook, desktop	First and second reconstructed models
4	3D scanner	Shining 3D Einstar®	Notebook	
5	3D model tolerance analysis	Geomagic Studio® (v. 2014.1.0.1706)	Desktop	
6	AR platform	Augment® (v. 5.6.1+30711)	Smartphone, desktop	
7	Artificial intelligence (AI)	Stable Diffusion® (v. 1.7.0)	Notebook	Graffiti simulation
8	Video conferencing, recording	Skype® (v. 8.125.0.201), Line® (v. 4.0.0)	Smartphone	
9	Historical maps	Quantum Geographic Information System (QGIS®) (v. 3.22)	Desktop	
10	Graffiti search	Google Lens® (v. C1.17.2405150)	Desktop	
11	Rapid prototyping	ComeTrue® (color prints)	Desktop	
12	Imaging	Adobe Photoshop® (v. 25.4.0)	Desktop	

(**b**)



(**c**)

Figure 2. (**a**) Research flowchart; (**b**) tasks, tools, and platforms; and (**c**) three-dimensional reconstruction process.

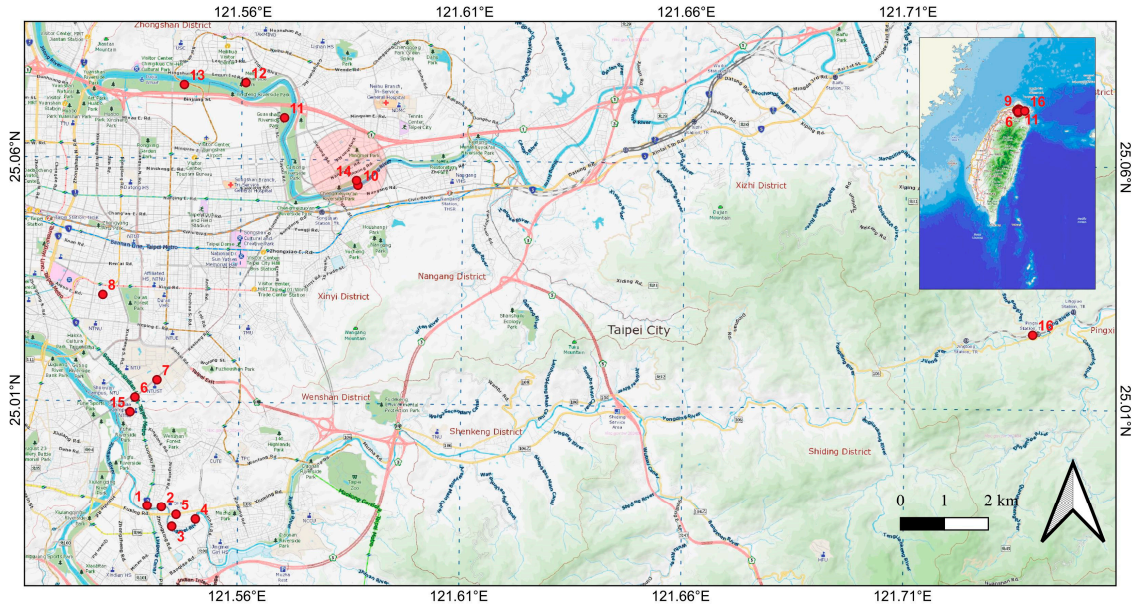
In total, 50 sets of artist or groups were included; according to reports from documented field models, this number is still increasing.

To facilitate the application, ready-made hardware and software environments were applied to integrate model preparation, interaction, and documentation together in AR. AR graffiti starts with the reconstruction of a 3D graffiti model; then, the model is uploaded and refined in the AR platform. This is followed by quick response (QR) code cloud access and site deployment and by smartphone image taking. The process ends with the documentation of the field outcome. The working data comprised AR models for the first 3D reconstruction of graffiti details and the secondary 3D reconstruction of the final 3D scene using screenshots for photogrammetric 3D reconstruction. The graffiti model can be created with the background as an influencing feature.

The method contributes a geotagged map for a self-directed tour for first-person AR object interaction in the preferred 3D format and dimensions, which is contact-free and supports the 3D printing of both reconstructed records.

2.1. Field 3D Documentation

Three-dimensional models enable a thorough description of spatial structure, which is connected to the deployment of a complete set. All creations can be inspected across walls, on walls and the ground, and by prelude or postlude. In total, an area of nearly 7930 m^2 was painted at the seven sites around Taipei Metro [16], as well as at a number of adjacent sites (Figure 3a). Field graffiti was documented in 3D models (Figure 3b) as an extension of the fabric. A series of pictures were taken on ground level to cover walls, building facades, or entire blocks. The models have detailed visual details (textures) and structural details for off-site inspections.



(**a**)

(**b**)

Figure 3. (**a**) Seven official sites and a number of observed occurrences around Taipei Metro; (**b**) three-dimensional documented field graffiti, as indicated no. 14 in the red circled area of (**a**).

2.2. The First and Secondary 3D Reconstruction of Graffiti AR Models and Background

Graffiti models were created through first and second 3D reconstruction processes (Figure 2c). The 3D graffiti were either modeled using Sketchup® or reconstructed with Einstar® 3D Scanner or Zephyr® using the images captured with a smartphone (Figure 4). The reconstructed models were trimmed, decimated, color-enhanced, and manifold-corrected prior to being exported to the Augment® platform. The uploaded models were further edited by adjusting the origin, orientation, surface normal, and dimensions for feasibility. Each AR model was assigned a quick response code (QR code) for remote access.

Figure 4. Physical and first 3D reconstructed models: (**a**) 3D physical model and printed replicate in a gray color; (**b**) 3D scanned model; (**c**) computer model; and (**d**) 3D scanned model. Models (**b**–**d**) are presented in AR form.

Multiple pieces of graffiti can be deployed sequentially by either adjusting the relative locations between the base graffiti model and the background for intentions (Figure 5) or by allocating more graffiti side by side to discern the new interpretation of the composition in the same AR environment. Any first reconstructed 3D model can be used as a base graffiti model to support secondary modeling as the combination of 3D statements with the urban fabric. AR interaction and context elaboration were manipulated through relative layout, scale, and personal preference of alignment. By taking pictures from different angles, final 3D models were created to record the results of x3D composition. The detail quality was improved by implementing 4K screenshots using a Sony® Xperia 1 II smartphone with a 3840 × 1644 resolution. Any visitor can contribute to social media and behavior using the newly generated context in preferred scenarios.

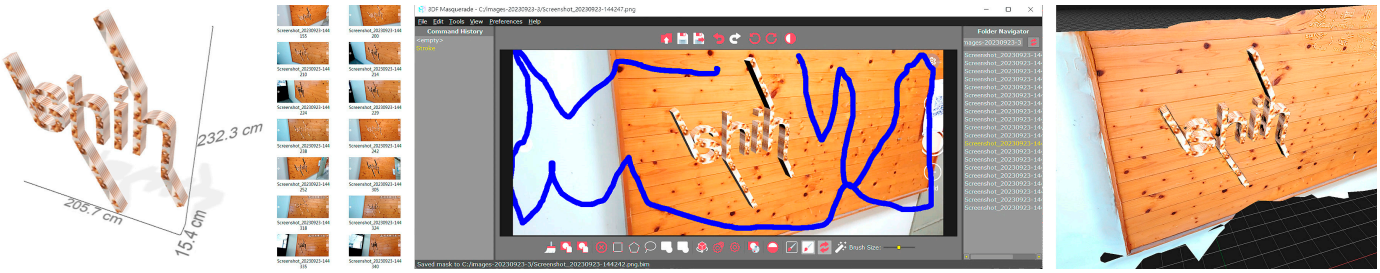
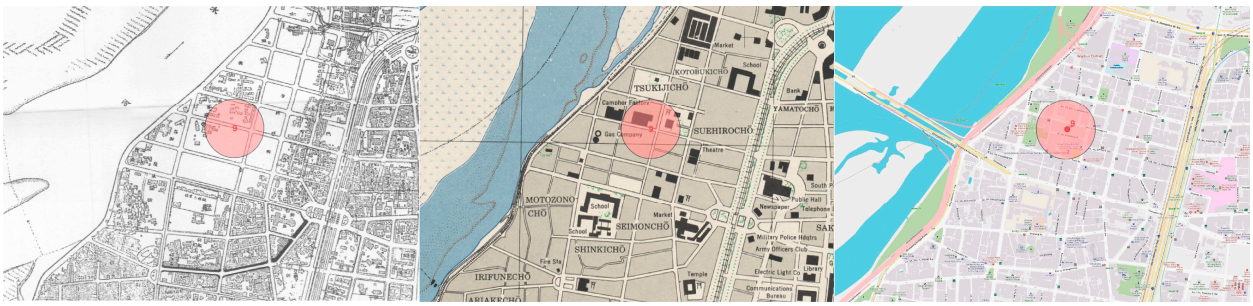


Figure 5. Second reconstruction: (**a**) model created using a 3D software; (**b**) screenshots of field composition; (**c**) second reconstruction process: blue lines are drawn to mask and remove the screenshot background; and (**d**) model created.

2.3. Urban Fabric Inspection

The majority of the graffiti in Taipei Metro was created at officially authorized sites and peripheral areas. Some locations showed a strong connection to local development and cultural fairs. By inspecting historical maps [48], the evolving fabrics revealed the deployment of constructions and their relation to open spaces and activities. The walls that house graffiti can be identified from their first occurrence in maps (Figure 6).



(**a**) (**b**) (**c**)

Figure 6. Evolved fabric exemplified from historical maps of (**a**) 1916 [48], (**b**) 1945 [48], (**c**) 2024 [48] around the circled area of graffiti site.

2.4. Three-Dimensional Prints

The 3D-printed model was an affirmative physical representation of the final data. The photogrammetric model was 3D-printed to document the results and to verify details originating from the AR interaction. The models were initially printed using single-colored photo-sensitive resin, using Phrozen® Sonic Mighty 4K in a 0.1 mm thick layer. A color model was also printed for texture verification using inkjet dyes on layers of powder (ComeTrue® T10). The visual and structural details were sufficiently self-explanatory to identify the composition of the first reconstructed 3D graffiti before and after being deployed on the background.

2.5. AI Virtual Infill vs. AR Field Infill

The seven sites presented different graffiti infill patterns according to scales, rules, spatial structure, and the artist responses to the layout. Although altitude can be calculated technically, the relative scale of the wall canvas to the easiest height at which a graffiti artist can work can vary from the height of one story to that of a tunnel or river embankment. The preferred shady conditions also led to the accumulation of a number of 3D graffiti pieces in a horizontal direction or vertical from the ground level to the ceiling.

The urban fabric characterized each site. In order to assess the differences, the existing deployment was performed again in Stable Diffusion® to predict potential new developments through variable combinations using (1) the size of the remaining unoccupied areas and (2) subjective judgment if spatial restrictions were applied. The variables included a classifier-free guidance scale (CFG) and denoising scale tested from a former setting of a typical wall, with/out inpainting. The graffiti canvas, which included peripheral fabric such as buildings, presented different results.

Even a fully occupied wall was still able to be filled in, for example, by overlapping. In contrast, an empty wall still found its scaled combination for infill, with a high tolerance of ranges. The original subject judgment of deployment was further measured to define the characteristics of a site or different sections of the same site, within upper and lower bounds. An alternative infill area was created using “inpaint” and Photoshop “smart selection”.

AI generation is difficult to assess. Typical variable sets were applied to present the difference between each site. Their current state and their potential future density of development were differentiated using a seed. The processes that were employed to extend the documentation of the existing fabric served the following purposes:

1. Assessing the void space (to define the pattern of regional restriction).
2. Illustrating the range of the diagram (CFG and denoising scale) as the base of comparison across sites and for future reference.
3. Defining the characteristics of a site or in different sections of the same site.
4. Facilitating a subjective judgment (if a spatial restriction is applied).
5. Delivering former assessed experience of spatial deployment.
6. Allowing on-going sustainable monitoring of the interaction between culture and the urban fabric.

However, the preference is not determined by the relative value. The result is subjected to an SD operation and the restriction of the "canvas" scale to the human scale. Based on the accumulation phenomenon, most of the generated graffiti was deployed within the former canvas boundary, i.e., the walls, and around existing pieces. The provided image boundary was able to distinguish between the result and additional areas outside the predefined area on pavement or utilities.

3. Results

In this study, the first 3D reconstruction of existing graffiti covered 300 m of authorized graffiti walls. This large number of creations makes people rethink alternative forms of graffiti, which can be facilitated by the use of current 3D technology in AR and smartphones. The second reconstruction was proposed and applied for field deployment and further documented through 3D printing.

3.1. Integrated Evolvement of Culture and Urban Fabric—Jingmei

The graffiti fair in Ximending, Jingmei, is hierarchically located between the city and the river bank sites (Figure 7). The viaduct is a former railroad. Jingmei River was an important tea transportation pipeline from the mountain area to the city. The rather limited space enhanced the allocation of the hierarchy of space for more diversified creation, with the main walls, adjacent walls, viaduct columns, bridge columns in the river, walls across the river, utility boxes on the bike route, the wall outside the grocery store, and white lines on the pedestrian walkway on the bank top. The urban context includes a sports park, a bike route (and related facilities), a night market, new skylines, bridges, the river front, an elementary school, and the edge of the region.

The historical background has created a unique urban context that hosts graffiti. This is also why it attracts so many international artists within such a limited area. By studying the graffiti here, the currently most active artists can be identified. The shady culvert under the street ensures a comfortable painting zone on sunny and rainy days.

3.2. Primary 3D Reconstruction of Existing Graffiti

Using photogrammetric 3D modeling, seven authorized graffiti sites have been reconstructed in the Taipei and Taipei Metro areas (Figure 8). The sites are located in the central business district (CBD), under a street, and on banks on riverfronts.

Three-dimensional models have become an important measure to convey creative intention in an enclosed space, particularly in tunnels. Their perspectives facilitated inspection when rotating and scaling were applied. For example, a top view showed a glimpse of a signature in front of graffiti on a wall. The signature, which would usually be ignored, was actually found on the ground (Figure 7f).

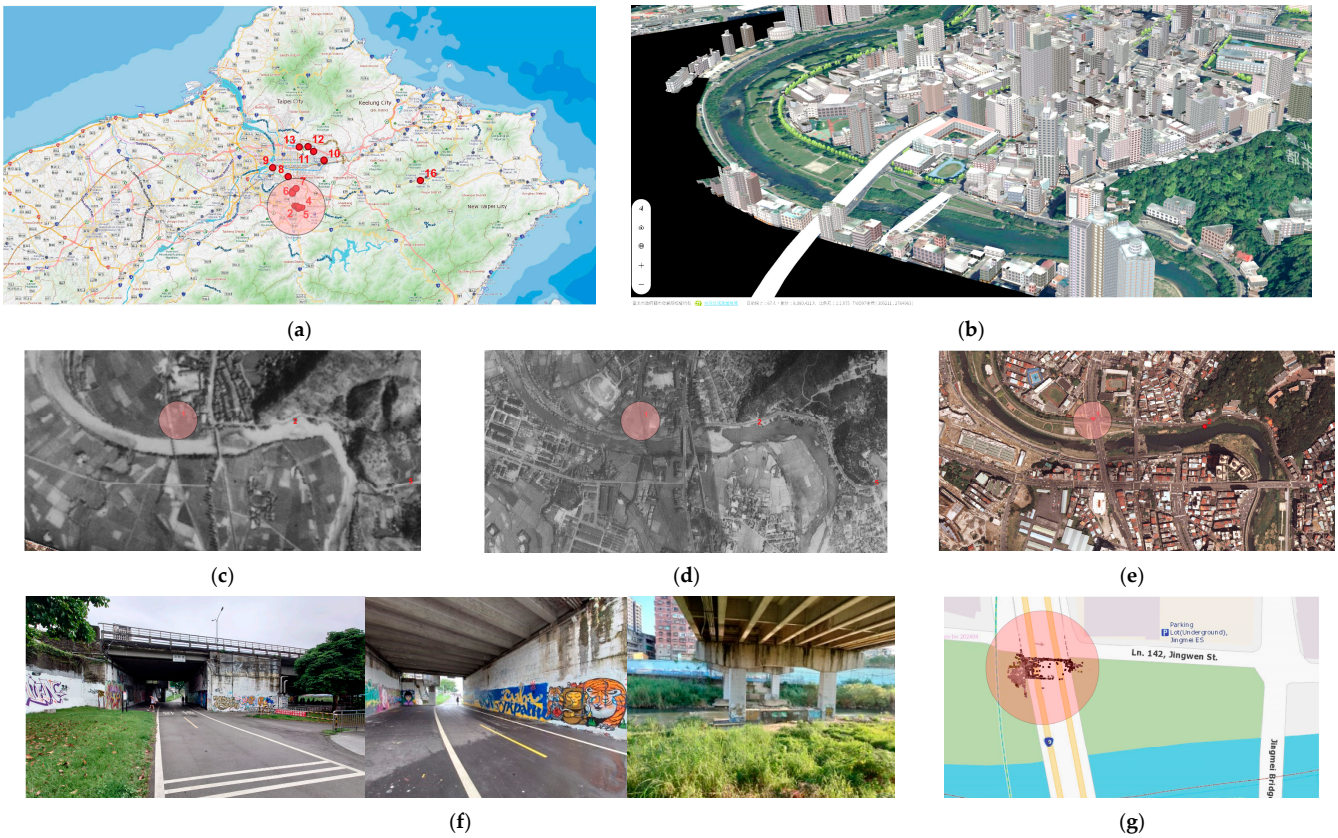


Figure 7. The evolving fabric around the Jingmei graffiti area (red circled area): (**a**) northern Taiwan; (**b**) 3D urban model; (**c**) 1947 aerial image [48]; (**d**) 1963 aerial image [48]; (**e**) 2003 Google® Maps image, where a new riverfront recreation area and bike routes have been added since 2011; (**f**) field scenes; and (**g**) aligning 3D point cloud model and QGIS® (Quantum Geographic Information System) within the circled area.

Figure 8. The images of three-dimensional model of public graffiti sites on river embankment: (**a**) in different scales; and (**b**) at different locations.

3.3. Field Deployment and the Secondary Reconstruction of Graffiti and Background

Three-dimensional graffiti were applied in reality (Figure 9) using specific designs (Figure 10). Subjected to situated themes, it acts as a self-created 3D virtual sticker that can be downloaded onsite. It was easy to scale, rotate, and move. A parallel side-by-side layout was the most straightforward composition. Multiple stickers were composed in balance, negative space, or symmetry with context already applied by former artists. It took less than five minutes to finish one AR scene, which can be preserved for future reference.

Figure 9. Field deployments of first reconstructed models: (**a**) graffiti on utility box using last-name characters; (**b**) foreground and background differentiation using 3D-scanned wood texture; (**c**) graffiti with the moon in the Mid-Autumn Festival; and (**d**) offsite and field deployment using seats and frames of different textures and forms to join the conversation made with existing graffiti or the environment.

The simplest and most popular type of graffiti is that representing personal identity, such as 2D or 3D signatures. I found that context elaboration was the most interesting part of this, such as impromptu additions by artists in the field or malicious marks on a portrait.

Similar to the sematic application of emoji icons, one of the best approaches is to allow constructive communication between former and current works. A multiple tentacle form design, which relinks graffiti elements, provided more engaging opportunities. For example, a typical design of two extruded linear members helped frame the moon. I also developed semi-transparent murals (Figure 10b) for easier alignment with the background through a richer mixture of depth. In general, puzzle-like 3D models enabled more gestures and depth when viewed from multiple orientations. In the theme of "Have a seat!", people can place a small bench in front of the wall to enjoy the sight of graffiti or a scene, like seating in a museum or yetaixi (i.e., an open stage opera in Taiwan), to symbolize physical presence.

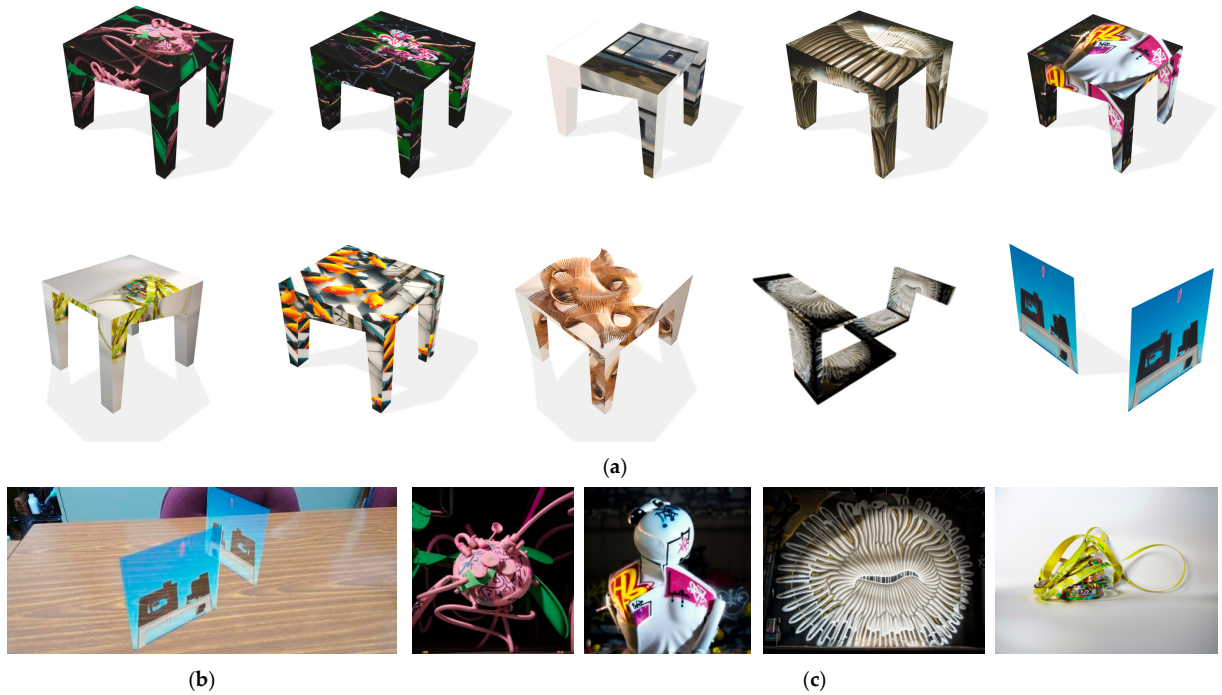


Figure 10. Three-dimensional AR graffiti models: (**a**) benches for "Have a seat!" and picture frames; (**b**) semi-transparent overlay; and (**c**) graffiti source image sets.

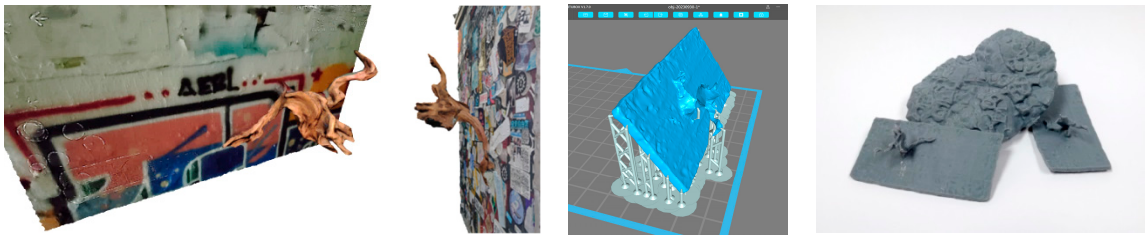
Field deployments of the first reconstructed models usually presented sharper edges in screenshots than the second reconstructed ones (Figure 11). However, the free-formed models usually presented better final shapes than the ones with orthogonal faces.

Figure 11. Second reconstructed models combined scenes and stools of different textures and forms.

3.4. Verification of 3D-Printed Model for the Base Models and the Second 3D Reconstruction

Verifications were made of the first reconstructed models, the base models, and the second 3D reconstruction in the 3D printing process (Figure 12). The 3D physical models enabled a close inspection of the earlier deployed result in the field. Both the virtual and physical models were inspected from different orientations in order to highlight the conversation between the AR model on the foreground and the context in the background. The models document and confirm visits, as an extension to the scenes in Augment®.

I found that the screenshots of AR models were better when captured using the 4K smartphone, enabling the most acceptable structural and visual details quality.



(**a**) (**b**) (**c**) (**d**)

Figure 12. (**a**) Model of 3D graffiti with the background; (**b**) model of 3D graffiti with sticker board on the background; (**c**) 3D printing interface; and (**d**) 3D-printed results.

3.5. AI Infill

A more aggressive approach was to add self-created graffiti to the empty parts of the walls. An image is still needed to generate the graffiti, with the style adjusted in Stable Diffusion® (Figure 13). However, the desired style needs repetitive training to meet one's requirements.

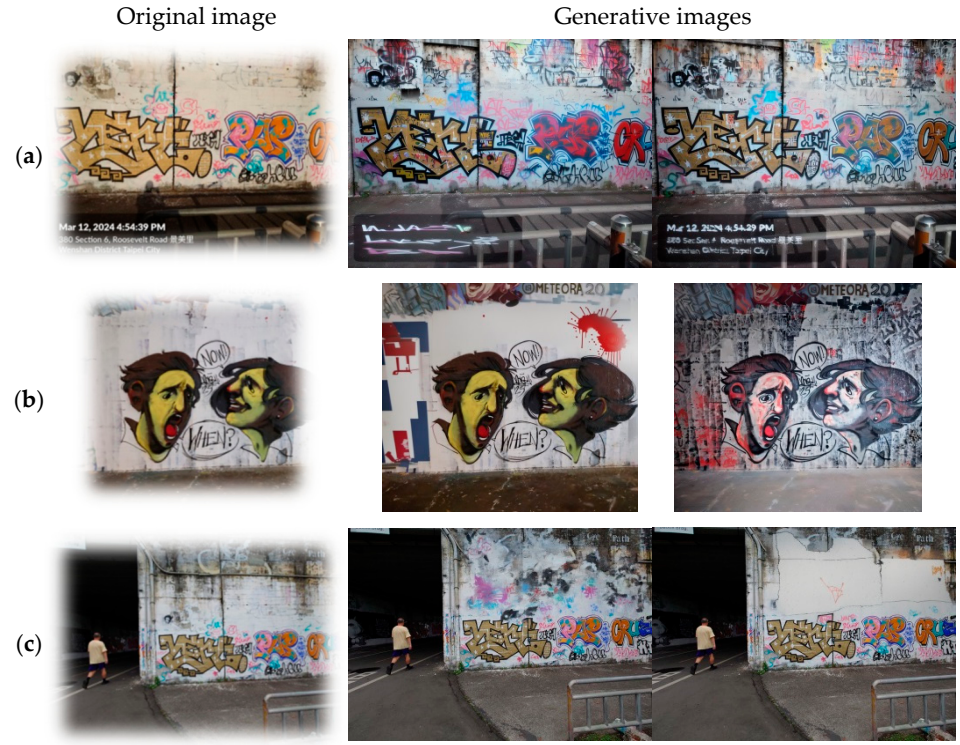


Figure 13. The infill of field images: (**a**) instructP2P (1912504687, 2797104547); (**b**) inpaint, instructP2P; and (**c**) inpaint.

In the set generated from the campus, Adobe Photoshop® was used to define the empty regions and to further assess the relative percentage. The divergent selective tools enable a well-controlled region for generative AI, although the final scaled effect may imply less divergent outcomes.

4. Discussion

The concept and method presented in this study allowed for collaborative assistance in the metaverse, enabling free communication between the virtual and real worlds. The complexity of the graffiti layout was interpreted through a novel and simplified AR-based reconstruction process. By referring to the existing context, the sequential reconstruction process cross-referenced and documented field hierarchies at the same time. Although

graffiti are generally presented as static, their deployment and execution usually accompany the scene and add dynamics to it. The interaction between dynamics and AR reconstructed the spatial hierarchy using a virtual signature and name card, as part of cultural consumption.

4.1. Graffitization and Spatial Hierarchy Reconstruction

Graffiti enables a spatial journey that can be interacted with in a self-guided virtual museum. It is easy to interact with the "cloud-accessed AR 3D stickers" multi-dimensionally. A city becomes an interactive museum housing a personal gallery of graffiti. The combination of timing and the Mid-Autumn Festival exemplified an occasional openness to a self-governed and defined cultural landscape. AR graphitization was found to reconstruct the field context on demand.

4.1.1. Open Environment of Reconstructable Context

AR provides an open environment to create new context on existing 3D models of the urban fabric. Through the use of repeated screenshots of physical objects and the AR interaction process, the results of the former reconstruction process were also reconstructable. This is an open documentation environment for situated reconstruction of new culture context from field spatial structure.

4.1.2. Freedom on Demand

AR graffiti provides an intangible version of this subculture without a physical space. The virtual museum metaphor has presented a flexible spatial structure, allowing canvas-free and cloud-based content delivery. As a result, AR-based interactions enable various forms of graffitized freedom to be accessed on demand: such as the museum (move a museum to you), delivery, spatial structure, canvas, management, interpretation, statement, and production.

4.1.3. An Architect of Graffiti

The graffiti on surfaces is not much different from the designs made by architects. Artists are usually involved in a number of social activities and create designs, in the same way that architects do with furniture, interior design, buildings, and urban design. The gradually expanded experience demands a more exposed stage to house the graffiti or design. The stage, in this case the urban fabric, actually allows more involvement of audiences and artists. Since traditional graffiti merely represents a one-way interaction with the surface of a building, to govern the performed graffiti should involve both the artists and architects.

The key point should be the opportunities of interaction on a broader stage that have naturally evolved or been purposely created for a diverse range of individuals. One of the interactions, which is conveniently facilitated by AR using a smartphone, contributes to the already enriched chain of production, personal involvement in a new site, and new tourism experiences that connect individuals to artists via cultural and social behavior. Audiences are able to scan a graffiti QR code, apply their unique personal interpretation, and upload it to social media or even tag it in Google Maps® at an art fair held anytime and anywhere.

4.2. Hierarchy Evolvement in Virtual Signature and Name Card

Graffiti represents a virtual signature made using texts or graphics. This virtual signature connects to personal identity through the creation and reconstruction of graffiti. It is a symbolic name card that functions like a sticker. The delivery requires different context setups in the real world and in AR. Virtual graffiti consists of three components: graffiti, spatial structure, and host media. A site is selected as the background, the virtual graffiti is downloaded by scanning a QR code, the layout is chosen, and a result is constructed for

documentation, management, or being redefined as a second level of identity for follow-up AR interactions.

Hierarchy evolvement represents how a virtual signature upgrades its social level to the urban context. Graffiti is created under a special order of space, subject to a social and hidden hierarchy. Evolved AR graffiti revises the hidden physical social hierarchy while also taking advantage of the urban spatial character. It is intended to broaden the possibility of hierarchical diversity in AR and transfer the on-demand metaphor to current social media. The easiest manner is to simply provide a QR code along with the content for public or authorized access and the management or documentation of acts.

Identity Propagation

The rich identity of Jingmei contributes to context propagation by making the most of walls. Identity propagation took advantage of the spatial structure through (1) cross-space (or-wall) composition of the same set of graffiti; (2) prelude or postlude; (3) bulletin board takeover; and (4) declaration or replotting of territory (Figure 14). Using the same color scheme, foreign identity can be found in the support for Ukraine. Propagation is contributed to by stickers or self-adhesive graffiti in the mass production process and by sticker graffiti in AR.

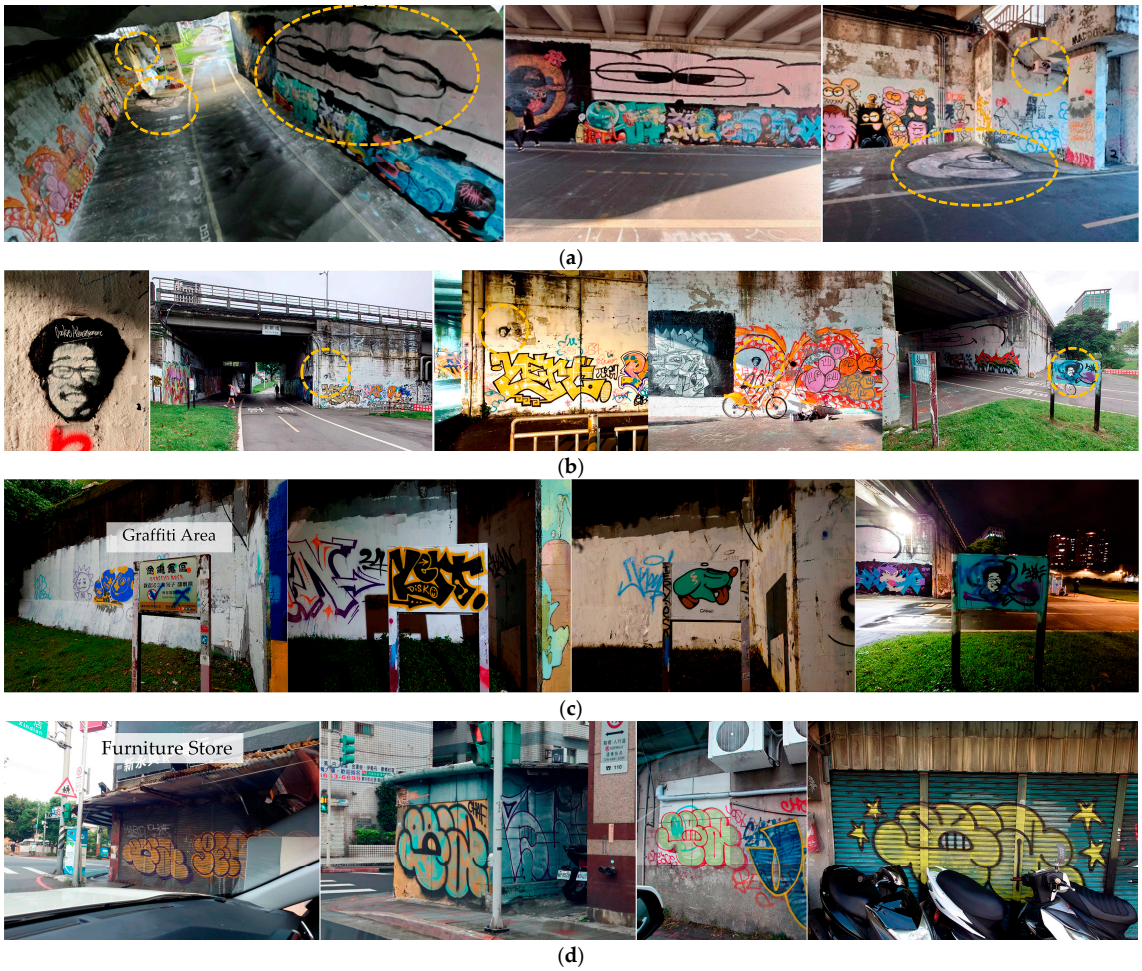


Figure 14. Spatial structure reinterpreted via identity propagation of graffiti: (**a**) cross-wall composition; (**b**) prelude or postlude: at least three personal icons deployed outside the main graffiti; (**c**) bulletin board takeover in front and back; and (**d**) same graffiti was used to declare or replot personal territory.

4.3. Cultural Consumption

Graffiti represents the interaction between culture and the urban spatial structure. Cultural production and consumption are related to contemporary urban regeneration [12] and consequently contribute to urban identity. The layout of graffiti, as a diversified form of urban regeneration, represents the unique identity of a city through decoration with statements and new types of subcultures. Those involved in graffiti are also consumers of media, and thus are influenced by the production and consumption of culture and the related creative industry.

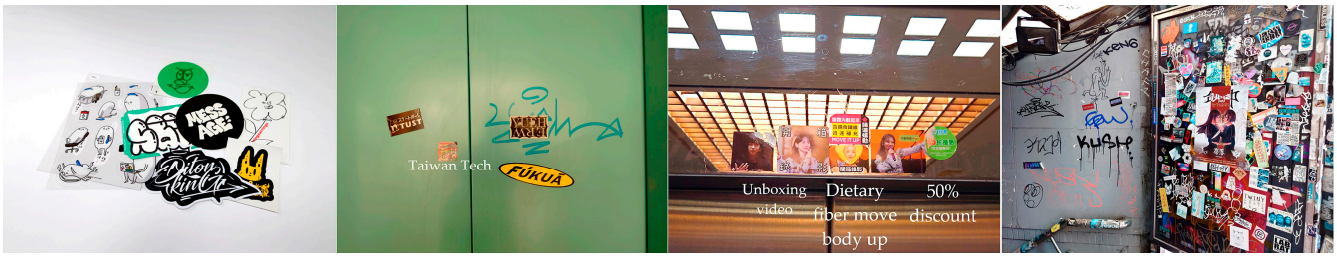
Cultural consumption is a form of collective memory that an individual may or may not have to participate in to be part of an updated identity. New graffiti have combined smartphones, internet shopping platforms, cloud databases and access, and AR platforms to reflect the identity of a new generation defined by gadgets. Graffiti culture has become generation-enriched and defined by a production system that expands the individual social or technical experience of an era.

No cultural activity is isolated from tangible and intangible support. The regeneration of cultural identity requires the support of a business model and a production system. The behavior model of graffiti, if not supported by the business model, is subject to failure and raises conflicts between governance and those involved in graffiti, as well as surrounding environment concern and statement delivery. Issues may occur when the level of involvement in graffiti surpasses a manageable scale. Cultures of consumption in contemporary urban spaces need a business model to accommodate the subjective community and to facilitate public involvement.

Business models have to fit into the model of graffiti culture. Considering the scale, support, and behavior of business models, their fast application pace should support the slow pace of the traditional graffiti creation process. As a successful production system, the model already includes download sites, a billing system, tutorials, graphic libraries, interest groups or communities, and supporting groups and sites. If we consider commercialized graffiti as a new form of culture, the currently available standardization of the operational model of graffiti in business production has already facilitated the identity and regeneration of a new cultural model.

4.3.1. From Stickers or Self-Adhesive Graffiti to a Mass Production Process

Graffiti stickers represent opportunities to exchange friendship, record visits, express mood on the way to work, or convey future performance. The location where a sticker is applied is usually very thought-provoking. The scenario, wall, and timing contribute a complex setting. In fact, this setting needs to be maintained long enough to foresee or recall the intention. The short window of opportunity for creation sometimes stops graffiti from being deployed in time, as exemplified by the tools applied in a small elevator space (Figure 15).



(**a**) (**b**) (**c**)

Figure 15. Graffiti stickers: (**a**) purchased collections; (**b**) deployment outside and inside an elevator; and (**c**) deployment on a bulletin board.

The desire to propagate graffiti everywhere promotes the need for its mass production. Graffiti stickers are considered an evolvement of graffiti for easy and quick deployment. They allow an efficient distribution of personal IDs or icons. The intention can be found in the four types starting from the prelude or postlude. It is the artist's customized CPG (incl. FMCG). The size can be as small as a sticker, or as large as a wall mural.

Field observation has proven the intentions of, and solutions found by various creators. One of the differences between a sticker and traditional graffiti is the group collaboration required to accomplish a large piece of graffiti. Although compositions and signatures can be printed out and self-adhesive, the digital design and deployment process still provides an opportunity to gather team members as an important part of a group event, with the advantage of easy removal. The ritual is therefore maintained.

4.3.2. From Sticker Graffiti to AR

AR is considered a sticker-free form of graffiti, where it is free from traditional official governance and environmental concerns. The only limitation is that it is not ready for constant physical display. This could be addressed by assigning hot spots to invite people to contribute to a virtual piece at a particular physical scene. The presentation of a group-created result can be additively applied and re-documented in the same way as in the photogrammetry.

Graffiti AR is an open process. Although it may result in the development of specific personal sites to interact with, the original creator may use this technology to share an open wall as a demonstrative site on Google Maps®. The traditional mode of ID propagation now has more options to select from. The three-dimensional outcome has proven to be capable of three-dimensional output in this study. From the traditional manual creation process to sticker deployment and AR interaction, the openness of this approach proved that graffiti is an evolving process of culture that is not only environmentally friendly but can also be applied to a new form of social media consumption subject to a business (AR) and production model (CPG).

4.4. Self-Governance and Group-Governance

The self-governance of graffiti was made possible by applying computer-mediated communication (CMC) and an AR system to transfer behavior and outcome to a virtual space. Returning graffiti governance to people integrates the roles and tasks to enrich a resilient measure between artists and viewers. This is one of the most straightforward approaches to deliver host media from a physical space to an AR setup.

Furthermore, it is achieved through personal ritual and CMC to facilitate graffiti without requiring space or physical contact with a scene. Through its design and execution, graffiti recreate a spatial order to meet social order and production order, conveying the hidden or visible identity of a person, a region, or the public. New graffiti present a CMC-based management of hierarchy and identity to support more open graffiti environments, such as news agents, window shopping, online shopping, 3D reconstructions of spatial structure, or even a smartphone-based application. A personalized graffiti process, or a sense of ritual, has evolved in combined orders of freedom in unlimited reconstruction, an integrated business model, and a chained production platform. By controlling every stage of creation and promotion, the ritual evolves in combined orders of freedom, while also facilitating the self-governance of graffiti.

The advantage is that it can be applied wherever cloud access is available, instead of the traditional location-specific distribution and one-way communication from artists. In places where graffiti are prohibited, environmental pollution is reduced and the unlimited supply of virtual space allows for barrier-free creation, regardless of weather, lighting conditions, spray paint supply, or heights exceeding human reach. Furthermore, measures suiting local conditions can be adopted, i.e., either on the walls in an alley or in a culvert under a street. This approach also encourages individuals to participate in a group creation process, while still being able to apply their self-interpreted personal signatures.

Graffiti is a management process with a ready-made platform for individuals, the community, the society, and, most importantly, the culture. As seen in the online shopping experience of 3D models, end-to-end scalable AR and 3D platforms for visualization and communication [33,34] can be easily extended to cultural consumption. The AR platform provided an intuitive and user-friendly interface for interaction with multiple adjustments to the graffiti and proposed new scenarios on the background. As a result, reconstructed governance is anticipated in geographic distribution, context elaboration, and the engagement of graphic hierarchy.

Physical gatherings, like meeting team members or other groups, are similar to the sharing of geo-coordinates by players of Pokémon Go® in the field. Pokémon Go® can be used as an example to explain how crowds can be brought to a specific location, such as a site to create and redefine new graffiti. For example, Taipei Train Station is one of the most popular sites in Taiwan. Players can enjoy air-conditioning with the least movement for engagement and team fights.

The production of AR graffiti through shared 3D data and distributed cloud access is unlikely to create governance difficulties compared to the pollution made by the traditional mode of creation. By making it possible to cover older graffiti without the creator noticing, AR is a less destructive platform compared to a physical takeover in the field. A safety distance is maintained during group behavior. This is different from subculture-centered graffiti exploration and deployment. The field deployment makes people engage with the urban fabric beyond the last stage of the building information model. The post-design reactivates the everlasting as-built state and enriches a new BIM state of a design.

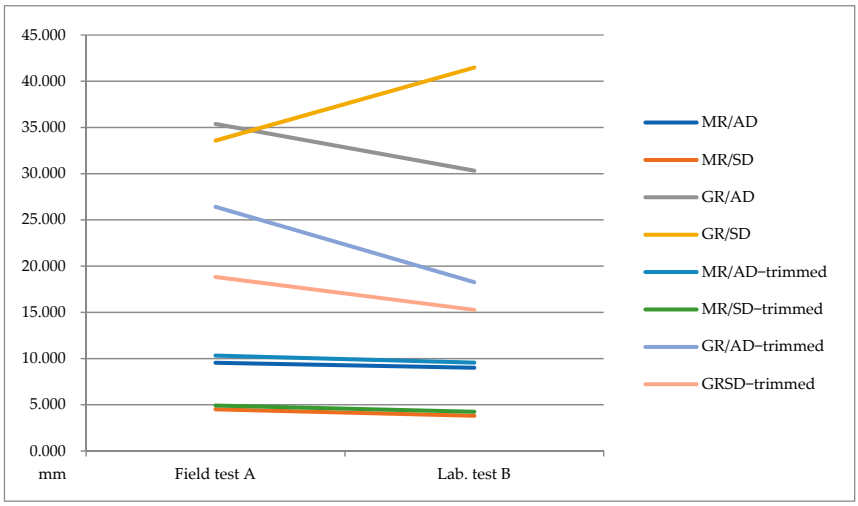
4.5. A New Brand of Media and Governance

Its involvement in related business and periodical promotion has enriched the nature of graffiti as a creative cultural brand. In additional to painting-related stores, there are shop-based groups that usually gather for new collaborative designs. A brand has evolved from the personal management of graffiti to a group learning process for new artists. It represents a new application of social media that is for display and promotion only. For additional engagement, AR QR codes can be an easy entry point to share personal intention in graffiti, similar to exchanging name cards or using emoji icons with a special style.

4.6. Quantification

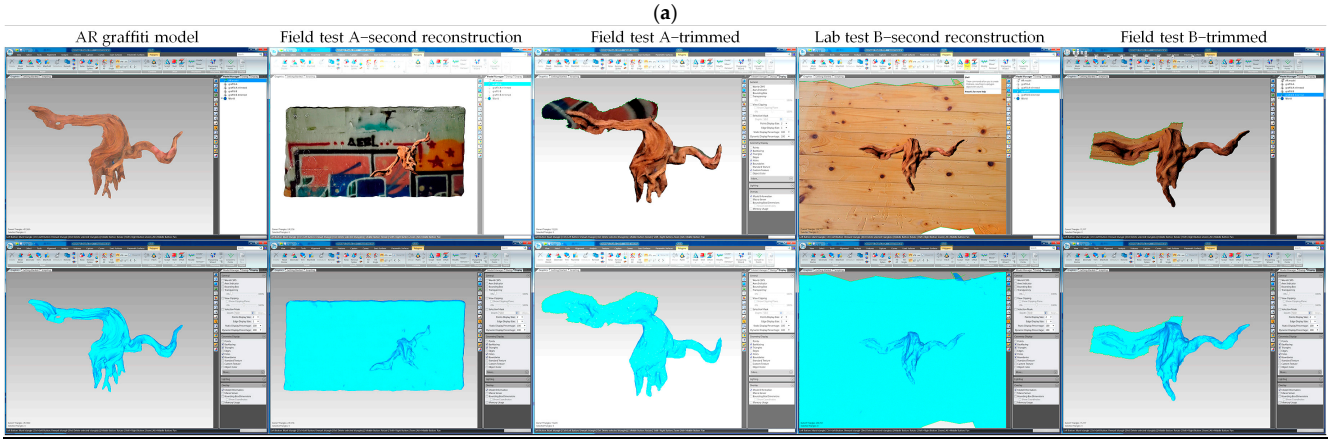
The quantitative measure was only made by evaluating the reconstruction of the graffiti from the first to the second one by average distance and standard deviation computed during alignment in Geomagic Studio® in two sets of data (Figure 16). The AR model, a convex-like shape, was tested regarding how the shape might be changed between a 3D-scanned model and photogrammetry model, in terms of sharpness and the recessed depth of details. The trimmed model removed the 3D background, which could be much larger than the size of the target graffiti and had lower value because the compared area was reduced around the graffiti. Working in laboratory conditions would allow for more control of the screenshot orientations than in field tests.

Both the 3D-scanned model and the photogrammetry model are reconstructions of physical models. The reconstruction was better for free-formed objects with deep textures than for an orthogonal-shaped surface. A convex shape was reconstructed better than a concave one because limitations regarding the depth of field may prevent the taking of pictures of the scene from all angles. In general, the 3D-scanned model presented the best result in 2D screenshots compared with the results of the photogrammetry (Figure 4) or 3D reconstruction result. For documentation purposes, the 2D screenshots of the field background with the first reconstructed model (Figure 9) presented better visual details than the renderings made for the second reconstructed model and background (Figure 11).

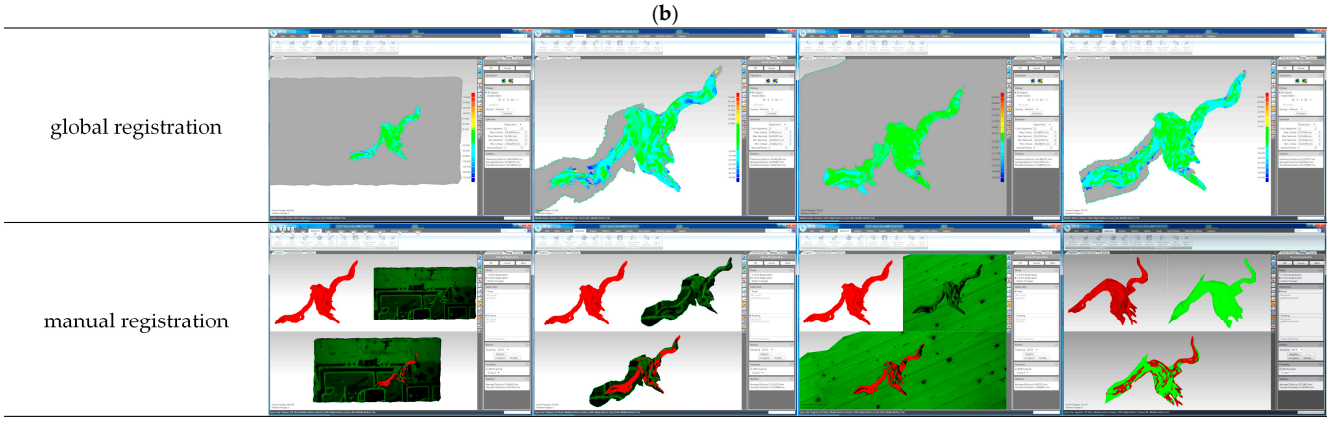


MR: manual registration, GR: global registration, AD: average distance; and SD: standard deviation.

(**a**)



(**b**)



(**c**)

Figure 16. Assessment of model configuration: (**a**) comparison by checking the alignment statistics; (**b**) AR graffiti model and field reconstructed 3D models; and (**c**) global and manual registrations with untrimmed and trimmed boundaries.

4.7. Limitations and Uncertainties

The graffiti that was created using AR presented a tradeoff between physicality, which is tangible and authentic, and virtuality, which intensifies social significance through internet and social media. The co-existence of current physical graffiti and social media is not that much different from the graffiti created using AR, since followers can create a more direct conversation with the original artists in front of the physical one in a virtual form.

The loss of tangible physicality can be compensated for by the wider spread of social media. Instagram® is already used in this way by many local artists. The AR-based promotion model could even exceed the current shop-based stronghold by using a virtual entity that followers can share, experiencing the same joy as the artists, using personal electronics and APP. It is anticipated that a new bond could be forged between artists and followers. They could be brought closer together as stage performers in the field or enlarged in scale through social engagement. Although there may be limitations for people that are off grid, social media could be considered an extension of physical media.

How long can graffiti live? Its significance matters, perhaps. While AR graffiti engages with more people through cloud access, whether popularity accelerates like graffiti stickers, or decreases like non-fungible tokens (NFTs) remains to be seen. In any case, it is certain that any person can now create graffiti and engage with it in a new way.

The temporary nature of virtual graffiti and personalization can be mutually beneficial. If social unrest can spread from TikTok®, YouTube®, or Instagram®, social significance can also be part of the promotion. Graffiti sticker has obtained a mass personalized appeal through a much-depersonalized CPG (or FMCG) business model, as have emoji icons used in smartphone apps. AR can be applied in a personalized or depersonalized manner, not just in the relation to the nature of graffiti AR.

5. Conclusions

The photogrammetry-to-AR method has proved to be an efficient modeling process, especially when the same ubiquitous smartphone device was used to take pictures and simultaneously interact with a real environment. The featured abstraction and comparison constituted the basic design of the graffiti for articulating and inspecting regenerated identity. In comparison to the existing form, graffiti graphics were reinterpreted or reconstructed as directly involved statements in contact-free personal signatures.

The creation of graffiti is part of a two-way process. Followers and audiences should be invited as part of the creation process to reclaim statements or revise governance. Contact-free graffiti no longer need to be created with no one around. The process can be broadcast through the internet anytime and anywhere through apps and smartphones. AR-based self-governance can be extended to any landscape or heritage, shared with the public, and support post-visit geotagged 3D documentation.

The cultural landscape can be ARized similarly to social media, with a similar distribution behavior, or similarly to how the hot spots on Google Maps® can be shared as "stickers". The tangible representation symbolizes intangible meaning through the interaction of graffiti without a space in AR. The cultural map of graffiti stickers has created a tour of ritual and the deployment of self-governed contexts and statements.

Future research can emphasize the precision of recursively made 3D reconstructions without losing the details. If possible, AI-based graffiti creation should also be developed in the early building design stage to foresee or simulate possible locations and patterns of graffiti after the occupation of the building.

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