

Street-ARt. Communication of Street Art Works Through Augmented Reality

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Abstract

Street art is a growing global phenomenon. The frequent appearance of works, projects and events reveals its increasing social and cultural role worldwide. Unfortunately, Street art creations are often hardly visible in urban areas. Besides, few national and international databases collect the characteristics of these artworks. The chance of digitising artworks represents a way to gain these cultural paths on the urban areas, providing an additional tool to understand and interpret it, connecting with other creations in the same area, freezing their memory, and mapping its change over time. Street art is characterised by aspects that make it unique in the artistic panorama. The contents' democratisation and the work's physical decay are two pillars. Any digitisation and communication project should consider them carefully, proposing a knowledge model respectful of the artwork. Augmented Reality (AR) is a representation tool that achieves that delicate balance between the real and the digital, enhancing both specificities. The chance of connecting the artwork with descriptive and multimedia content can significantly improve its visibility, enhancing its presence in the urban context. AR can also fill this information gap in the artwork, providing a stimulus for multigenerational reading that brings different audiences to Street art, integrating with existing platforms and proposing new cultural paths. The authors** start with artwork digitisation, showing experimental data about the connection between image deterioration and image AR recognition. Besides, they show some possible applications in Rome through a critical domain analysis, opening some future multifaceted scenarios.

Keywords

Anna Magnani; art impermanence; augmented reality; feature recognition; marker tracking; Rome

** Authors developed the research together. In the writing step, authorial attribution is the following: F.C. is responsible for paragraph 6; E. I. wrote paragraphs 1 and 7; A.M. worked on paragraphs 2-3; finally, M.R. is responsible for paragraphs 4 and 5.

1. Introduction

Street art, considered a free graphic representation of artistic subjects on vertical or horizontal surfaces, is experiencing a moment of a global renaissance. These representations, which characterise the urban scenes, belong to everyone: creators, citizens, tourists, and critics. It is an art without boundaries, free from museum routes but limited in protection and affiliation (Balocchi, 2012). Street art has different goals. On the one hand, it wants to enhance degraded urban areas and architectural structures, introducing new signs of cultural rebirth. On the other hand, it radicalises the memory of places (Ciotta, 2012). The increasing number of artists confirms the

growth of this phenomenon on a national scale, promoting events such as Super Walls (<https://www.biennalestreetart.com>) or CHEAP (<https://www.cheapfestival.it>). Besides, there are many events and projects worldwide, like SHINE Mural Festival in Florida (<https://www.instagram.com/shineonstpete>), Upfest in Bristol (<https://www.upfest.co.uk>), Street art Fest in Grenoble (<https://www.streetartfest.org>), Afri-cans Street art Fest in Kampala (<https://afri-cans.org/street-art-festival>), HK walls in Hong Kong (<https://hkwalls.org>), MURAL Festival in Montreal (<https://murfestival.com>) and Brisbane Street art Festival in Brisbane (<https://bsafest.com.au>). Different international projects aimed to connect artistic works within urban fabrics in Madrid

(<http://madridstreetartproject.com>), Barcelona (<https://www.streetartbcn.com>), Lisbon (Guimarães et al., 2016), Glasgow (<https://www.citycentremuraltrail.co.uk>), Vienna (<https://www.startnext.com/viennamurals>), and USA (<https://streetartunitedstates.com>).

Instead, Street art shows a slow development in areas with strict regulations, like the movement “Streets are yours” promoted in Japan. In China, Street art was applied to the walls of many schools in 2016 to promote the return to class in disadvantaged areas through the project “Back to school China” (<https://www.graffitistreet.com/back-to-school-street-art-project-china-2016>). Finally, the foundation of extraterritorial associations that promote Street art linked to specific global issues, such as slavery and child labour, is growing (i.e., <https://streetartmankind.org>).

From this first concise and not complete depiction of the development of Street art, several compatible or conflicting features emerge. The desire to achieve a high level of visibility of individual works and to be included in a network of local or global knowledge necessarily clashes with the desire to be outside the schemes and rules that often manage the events that provide such visibility. A second element, closely related to the first, concerns the contradiction between rules and laws and the desire to produce illegal and outside-the-rules acts. This condition engenders a paradoxical situation in which cities present free and permitted zones alongside forbidden parts. The channel of the Danube that runs through Vienna (German: *Donaukanal*), which makes this alternation a distinctive feature, provides a striking example. The relationship between the sense of belonging to a place and freedom defines a third element of interest. Indeed, while reflecting the artist’s soul, training, and purpose, the works become an integral part of the places, reinforcing the sense of belonging to a specific city area. However, the artists mainly desire to be free and not tied to a place. In this regard, the layering of works determines a multi-cultural process in which the same place becomes an expression of different cultures over time, connoting an ever-changing sense of belonging. Finally, it is essential to emphasise the scalability of the message in the Street art, which can move from strictly local content (as in the reported Chinese school example) and on a specific theme versus global issues of ecology, and human rights or other.

The topic’s relevance has led to the creation of journals devoted to Street art, such as the Street art & Urban Creativity Scientific Journal (SAUC), and thematic journal issues devoted to the Street art domain (<http://disegnarecon.univaq.it/ojs/index.php/disegnarecon/issue/view/27>), or specific workshops (Casimiro, 2019). In a global communication framed by the massive use of images and videos, the growth of this artistic movement may benefit from these digital channels. The link between artworks and descriptive or multimedia content can significantly improve Street art understanding, valorising the presence in the urban context. Augmented Reality (AR) is a tool to read beyond the visible, providing a multigenerational stimulus that brings different audiences closer to Street art proposing new cultural paths. A cultural approach compliant with the Street art principles and its contents requires answering the following questions:

- Can the digitisation process be respectful of some Street artwork values? What is the balance between permanent digital data and temporary art?
- Could the interest in applying AR tools overcome the attraction in the artwork?
- What is the relationship between the chromatic-graphic aspects, the state of preservation, and its AR recognizability? Is there a relationship between the acquisition characteristics of the cameras, the acquisition distance and the image recognition process which lead to the AR activation?

The authors try to answer these questions by proposing a critical analysis of the main characteristics of Street art and the pros and cons of AR in the domain.

2. Analysis of Street Art Contents

Urban art can be considered a wide container within multiple artistic currents, from graffiti to Street art, with specific materials, communication, and representation (Arnaldi, 2014). Often Street art describes contemporary subjects or political themes, provoking people and creating a deep relationship with public spaces and inhabitants. Some features are relevant for understanding the Street art essence and establishing a respectful relationship (see Figure 1). The “democratisation” of content and communication is the first one. Street art has become



Figure 1. A Venn diagram of the democracy and impermanency pillars in the upper part, with related sub-items. On the bottom are some images of creations (acquired by the authors) that reflect the two domains. The intersection has in the digital domain, specifically in the AR, the field that preserves both aspects.

a socio-cultural phenomenon defined by changing connotations with no precise edges. For these reasons, the artistic subjects expand the audience to all ages and cultural backgrounds. The flourishing of many events organised by cultural associations collaborating with public institutions exemplifies this trend, leading the art into a more framed flow. On a national scale, the Cultural Association MURO (<http://muromuseum.blogspot.com>) promotes festivals and urban art projects, fostering the idea of a diffuse museum of Urban Art in Rome. In the same district, the social projects Big City Life in 2015 and Moltitudini - Big City Life in 2018 (<http://www.bigcitylife.it>) allowed requalifying some buildings in Via di Tor Marancia and Tor Bella Monaca. Other projects are “Diciamo Insieme Grazie” (<https://www.diciamoinsieme grazie.it>) and “Dominio Pubblico - MILLENNIALS A(r)T WORK - MA (r)T”; the first left a testimony on the COVID-19 emergency, and the second brings up young people's contact the urban fabric and contemporary art. Despite these examples, several artists want to preserve a connotation of illegal activity and free experimentation, working in degraded urban areas or abandoned buildings. At last, art democratisation refers to the urban transformations and human sensory limitations that can neglect art accessibility.

The concept of Temporary Street art, named “impermanence” (Meschini, 2020), is a second pillar. Artists are aware of the limited durability of their works due to the materials and techniques used or due to the “illegal act” connotation that makes them subject to removal. Tears, vandalism, removals, thefts, and natural deterioration subject artworks, exploiting the incisiveness of the image through its dissolution. Some techniques are devoted to speeding the realisation and the communicative impact. They are often ephemeral results that become heritage imprinted in the collective memory. This latter is conceived in a participatory form to relate people and places through installations designed to be destroyed, torn, disassembled, and taken away in fragments as memories. They are subject to people's good decisions, bad intentions, and weather events, determining all their transformation during the time. The disappointment for the limited lifetime arises from external people, while the artists claim their crucial role in the art. Some other artists are searching for a new meaning of permanence in terms of techniques and experimentation,

assigning a function of environmental sustainability. The restoration of artworks, removing graffiti and tags that limit the art reading, represents a valuable example of permanence preservation.

3. Street Art Digitisation

The physical and digital worlds, framed in the Street art domain, highlight a complex relationship with apparently antithetical characteristics. The digitisation of artworks improves their visibility in the urban context, facilitating their search, accessibility, and classification (Novak, 2015) and digitally freezing their state of conservation (Rodriguez-Navarro et al., 2020). Few national and international databases collect artists' works and relative characteristics. An example is the Street art Cities platform (<https://streetartcities.com>), which catalogues and collects many Street art works worldwide, linked to a geographical map. In Rome, David Diavù Vecchiato and MURO association conceived similar projects, such as the GRAArt project (<http://www.graart.it>). It traces the history and myth of Rome on the walls of the Grande Raccordo Anulare, mending the cultural gap between the monumental historical centre and the suburbs (Brucoli & Battisti, 2020). A second project is STREETART ROMA (Artribune) which allows finding the artworks in the capital area within mobile systems. The project has a broad audience offering geo-data integrated with text, images, and videos. Finally, there are some examples devoted to single artists. Banksy Street art Treasure Map is a free app for IOS mobile systems dedicated to Banksy's works worldwide. Besides, Millo's official website (<https://www.millo.biz>) presents a map for exploring and viewing his works. In this framework, artworks digitisation and geo-localisation simplify the construction of virtual itineraries, strengthening different cultural and thematic connections. It also allows freezing creations, fixing their conservation condition in a digital trace. However, despite these pros, the digital replica lacks a physical relationship with its urban context.

The digitisation can provide additional content (2D/3D iconic-graphic info, static or animated data), simplifying the understanding of the representative mechanisms behind the artwork without interfering with a direct reading (see Figure 2 schema). Firstly, it can help reading the connection between different creations through descriptive information and links to the artworks, such as Sirante's “The Depo-

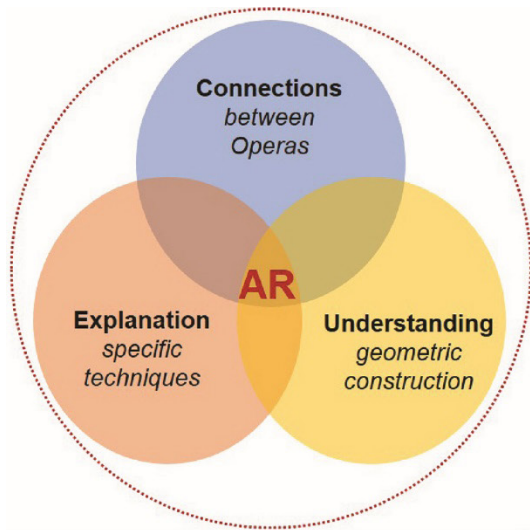


Figure 2. Types of activities and content conveyed by digital, particularly AR, result in the intersection of the types of digital communications of artworks. The authors have acquired pictures of the creations.

sition of Truth”, based on “The Deposition from the Cross” by the painter Rogier van der Weyden (see Figure 2a). A second application may explain particular techniques to achieve specific results, like Sten&Lex creations (see Figure 2b). According to black and white lines, they work with the stencil poster technique based on very fragile paper matrices. The artwork generates different perceptions according to the viewing distance, recalling the world of Optical Art. So, the artwork can be better explained by deepening the optics principles. Finally, it can be crucial to use digital data to explain the works’ geometric construction by referring to perspective principles. An example is JR’s perspective anamorphosis of “Punto di Fuga” artwork, a large-scale

poster art (see Figure 2c).

Augmented Reality represents a solution that may preserve the characteristics of the works and provides integrative digital content. Real and digital converge, allowing exploring information not contained or not immediately/visually perceivable (Metrick-Chen, 2015). However, the interest in applying this tool may overlay the attraction in the actual artwork. For this reason, it is appropriate to plan a critical design process that identifies the most suitable content, improving the art perception without replacing its direct reading and the relationship with the environment.

4. AR for Street Art

There are several steps, declined to multiple application areas (Russo, 2021), which may define an augmented reality process. Content democratisation, art impermanence, and image recognition are all crucial aspects of Street art applications in AR (see Figure 3). Urban art belongs to everyone, so democratisation refers to the user's domain, consistent with the purpose of the work.

The AR users range from children to the elderly. Accessibility is, therefore, a critical prerequisite, reflected in the type of device, the AR applications, the virtual interaction, and the content complexity. Smartphones and open-access applications are considered suitable solutions because, on the one hand, they are the world's most widely used photo capture and image recognition tool. On the other hand, the ever-improving performance of cameras combined with increasingly powerful graphics processors make them the most popular and convenient integrated system to use. The possibility of access to open source applications does not tie users to an expense, spreading their application. The level of interaction must be engaging and straightforward, en-

larging to a broad audience. Finally, avoiding trivial and too complex content is appropriate for promoting accessibility and meeting the interests of multigenerational people.

Data simplification and description must consider the audience, the work of art, the user experience, and the level of interaction (see Figure 3). The content linked to the work is critical since it defines the relationship with the work and the cultural growth of the user. First, it must be consistent with the type of work, offering insights of a geometric-constructive nature, transversal reading, descriptive content, or inspiration suggestions. Besides, the content visualisation should neither replace nor hide the work, highlighting the creation, and its relationship with the context, feeding a new experience and interaction. The content may range from texts to photos and drawings to interpretative 2D/3D models and videos.

Besides the content, a second AR pillar concerns art recognition techniques. The geolocalisation makes it easy to build itineraries, simplifying the recognition of artworks with low accessibility. On the contrary, it can lead to a possible mismatch in the artwork recognition, because it is invariant to the urban and artwork transformations. For example, the

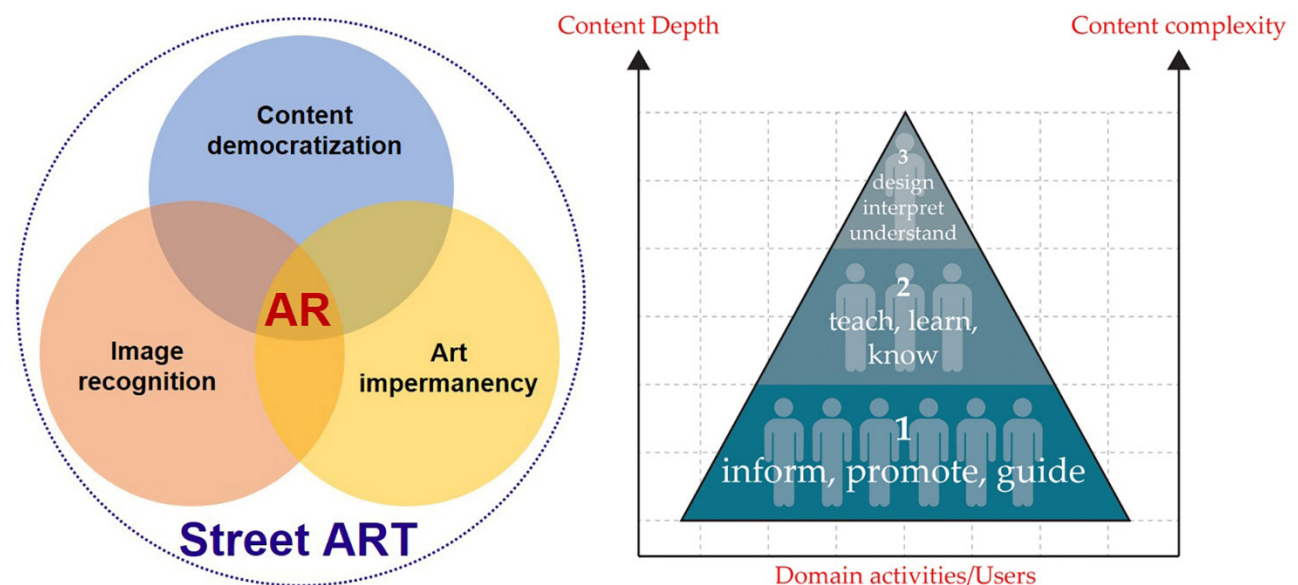


Figure 3. Two diagrams of the relationship between AR and content communication. Highlighted on the left are the most important aspects to remember when designing AR content to respect the work. On the right, the diagram shows the content learning pyramid, highlighting how the AR human target should focus on the bottom, with a low level of complexity and depth, to ensure the widest access.

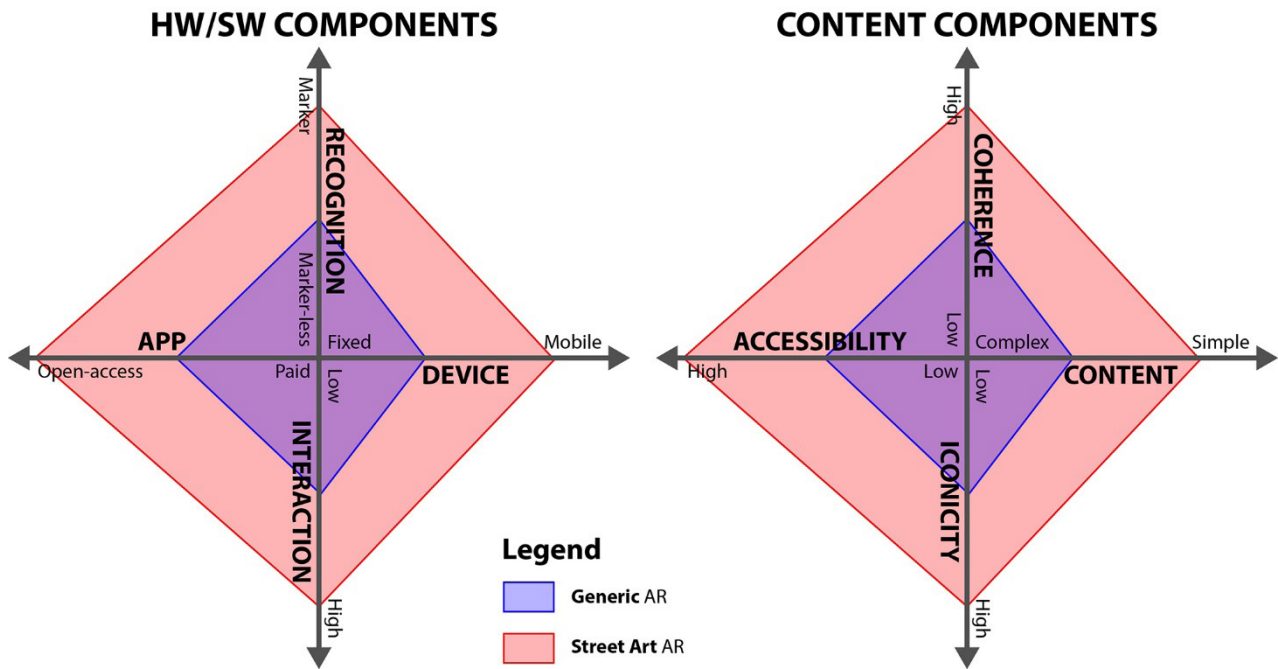


Figure 4. Star diagrams with main hardware/software and content components related to AR for Street art.

geolocation may remain valid even if, in the meantime, the artwork has been removed or the building has undergone changes. In all cases, therefore, it is unsuitable for preserving the link between art, its transformation, and the environment. Marker recognition, expressed through coded images or 2D/3D geometries, creates a direct relationship with the subject. It offers a more consistent solution with art impermanence, the context of insertion and access. This approach can show some limitations in the construction of itineraries and artwork visibility if they are in confined places (see Figure 4). In fact, it implies gaining a suitable position to frame the interested area. If there are obstacles (vegetation or artefacts) that prevent its recognition, the AR is no longer usable. This example highlights the strong relationship between the recognition process, the environmental conditions and the state of conservation of the wall representation.

Several AR projects for Street art communication and promotion have been proposed recently. MAUA (<https://maua-museum.com>) is an open-air museum project spread over several cities, allowing the transformation of the works in a participatory way. This project has ignited the interest in AR Street art, even if it suggests an overlap of graphic re-

interpretations that only partially preserve the reading of the original work. Besides, the desire to connect multimedia content to artworks with AR, improving storytelling and expanding their access, is a theme felt by several artists. An example is the free app *JR:murals* (Google Play and App Store), which allows interacting with some artworks and accessing audio-video content.

5. Analysis of AR for Street Art

The experimentation was quantitative and qualitative, analysing several factors influencing the correct visualisation of AR for Street art. Specifically, it investigated the relationship between the characteristics of pictorial works and their different preservation condition concerning their recognition by different digital devices. Different variants of the same work were produced to emulate some possible alteration effects of the artwork. The first test focused on computer extraction of the recognition value (score) by two different feature recognition algorithms: the one used by Vuforia and the one used by ARCore (Lanham, 2018). Both algorithms work on the recognition of feature points within the image. The Vuforia Engine¹ transforms the image into

1 - <https://library.vuforia.com/objects/image-targets-optimization-techniques>

greyscale before performing this analysis. In both cases, the algorithms identify high-contrast points, so the repeatability of patterns or the presence of similar pixels significantly reduces the value and, thus, the ability to be recognised as a target. The image scores allowed us to compare the two algorithms. It also led to some critical considerations in the relation between the state of conservation and feature recognition. Alongside this first phase was the second outdoor experimentation, which allowed for qualitative analysis. This step verified the scoring results, highlighting similarities and differences between the images. Besides, the ability of the camera to distinguish the work at a greater distance was investigated. It tried to connect the characteristics of the sensor and lens to the ability to engage the augmented content. Both experiments were conducted with three different smartphones: Samsung A3 (13 Mp, 4128 x 3096 pixels, f/2.4), Samsung S4 (13 Mp, 4128 x 3096 pixels, f/2.2), and One Plus 6 (16+20 Mp, 2160 x 3840 pixels, f/1.7). It allowed us to compare the different performances of the phones (camera and sensor) and carry out an initial comparative analysis based on the results obtained. All experimentation took place outdoors to simulate the light conditions closest to what is a shot of the original work. The content of the AR is a simple text, very small for data management but sufficient to verify the image's attachment to the content.

5.1. Quantitative Experimentation on Single Image Feature Recognition Algorithms

The first phase of quantitative experimentation focused on quantifying the number of features in each image. This recognition is carried out by applying recognition algorithms specific to each AR system. In our case, those of Vuforia and ARCore were tested. Three case studies were analysed, similar in scale and position, located in the Tor Bellamonaca neighbourhood: the work of artist Solo entitled "Jeeg Robot," (Figure 5a) the work of artist Diamond entitled "No Surrender," (Figure 5b) and the work of artist Musa One entitled "To Go Beyond." (Figure 5c)

Different variants were produced starting from the ortho-image (Figure 6, Img Type 1) to simulate physical alteration effects while at the same time going to verify the response of the recognition algorithm. Specifically, three different levels of colour saturation and transparency (25%, 50%, and 75%) were introduced to simulate the effect of

colour loss and surface washout due mainly to natural reasons. Then six layers overlap the original artwork, which gradually disappeared, replaced by the underlying surface. This effect simulates detachments and localised deterioration processes, often related to anthropogenic causes. Finally, we simulated tags in the base of the artwork, introducing the concept of superstructure between different artworks.

At this experimental stage, each image was analysed separately. It means that the value or "score" provided by the algorithm, corresponding to its ability to identify features within it, is relative to each image and not in comparison to an absolute condition of initial artwork. This relationship has been tested in the following experimental phase.

This first experiment showed some interesting aspects (see Figure 7). The algorithms work similarly but not equally. Therefore, it is essential to open some reflections on feature recognition as a function of camera working conditions and art variants, comparing the different behaviours of the two algorithms. On the most recognisable targets ("Jeeg Robot" and "To Go Beyond"), ARCore's algorithm is more stringent, in contrast to the less recognisable one. The level of transparency in the images determines the most significant variation, resulting in some behaviour dissimilarities. As for "Jeeg Robot," the features of the work make it well recognisable, and the loss of colour is invariant to its recognition. The appearance of the gaps only partially affects it. Instead, what causes the transparency of the colour dictates a sudden loss of recognizability. Similar behaviour can be seen in the work "To Go Beyond." On the other hand, a joint reflection on these first two works concerns that the incremental presence of the gaps does not generate an equally linear loss of recognizability. It is because a delicate balance between the work itself and the geometry of the gaps is probably engendered. As long as the image recognition process shift from the gaps (very well defined) to the artwork's original painting, the recognition capability decreases. However, with an essential presence of the gaps, they become a recognition element, and thus the recognition capability of the algorithm goes back up. Concerning the work "No Surrender," it is seen that the work has low recognizability due to the intense, dark colour and black pattern, as well as the presence of numerous uniform ar-

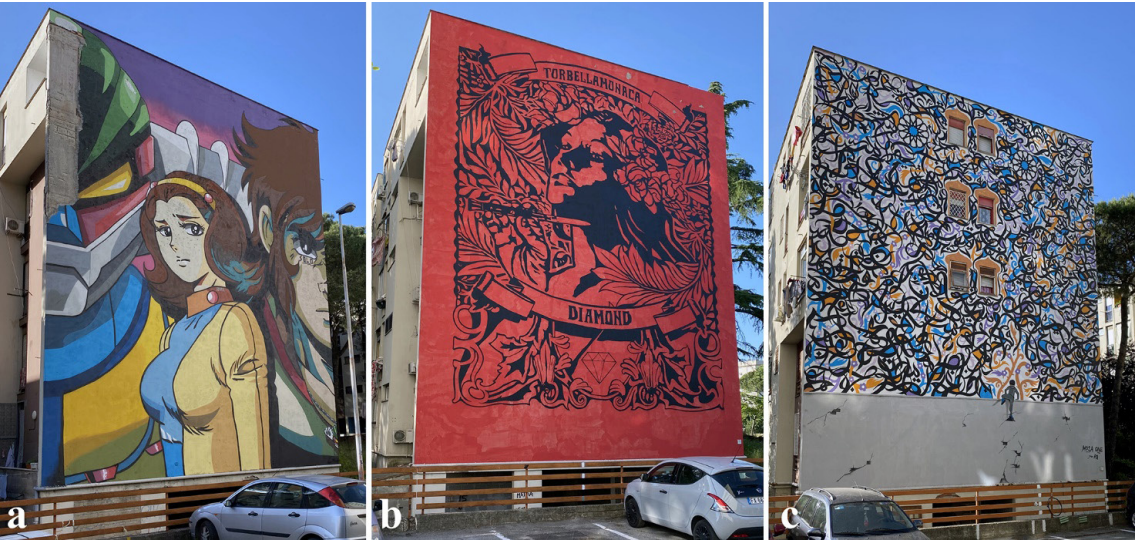


Figure 5. Three case studies analysed: a) Jeeg Robot, b) No Surrender, c) To Go Beyond.



Figure 6. Above is the diagram of the outdoor experiment. The image set refers to the work “Jeeg Robot,” but we replicate the experimentation on the other two works with three different smartphones. Bottom the three different scenarios of the experimentation on the three works.

eas. Both algorithms gain recognizability with the total loss of colour. The real change occurs when the work is no longer the main subject of recognition as much as the gaps, so a substantial increase is visible in that case. This step will also be highlighted in the experimental phase outside. Besides, we note for all artworks how the presence of tags at the base does not substantially change the algorithm's behaviour, given the small area involved.

5.2. Qualitative AR Experimentation on a Complete Set of Street Art Variation

The first phase of outdoor qualitative experimentation was based on shooting from close range (about 1 meter) a sequence of images printed on A4 size sheets. The AR exploited Vuforia's feature recognition algorithm, linking straightforward textual content. These 13 different variants for each work (14, including the original) were placed on the same exterior wall with the same illumination level. They were then photographed separately with the three smartphones at 1 meter, testing both the different behaviour of the phones on the different images and which images were challenging to engage with AR (see Figure 6, station 1). The summary data of this first phase are reported below:

From the first test, only two modified images gave recognition problems: the image with 75 % opacity and the image with the most gaps (see Figure 8). On the first one, different behaviours were evident among the three cameras. Specifically, the OnePlus6 was the best at linking AR content to all images with higher transparency. On the other hand, in the case of the image with many gaps, the presence of windows in the work of "To Go Beyond" probably made it easier to engage the information, which was not possible in the other two cases. Finally, we point out that the characteristics of the "No Surrender" work made it impossible to link it to AR content. The only additional test was introducing the image with the gaps into the targets. In this case, their presence made it possible to extend the reading for all cameras to most images with gaps (see Table 1).

5.3. Qualitative Experimentation on AR Application as a Function of Working Distance

The second test concerned the working distance (see Figure 6, stations 2-5). The three pictures were framed with two levels of feature detectability (original and low) initially at five distances (1 to 5 meters) signalled by ground targets. Progressively moved farther apart to test the maximum working distance of each phone. The following are the re-

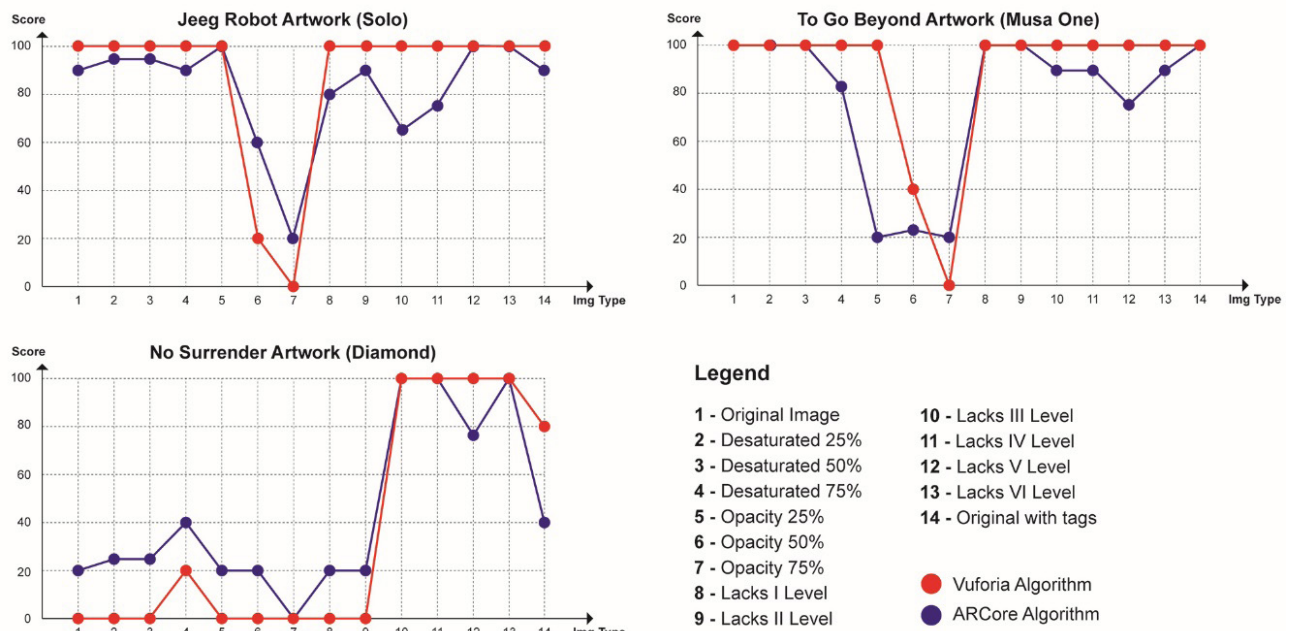


Figure 7. Comparative graphs on the score of different types of images according to the recognition algorithm and the work analysed. Vuforia values have been normalised on the 0-100 scale. The Type 1 correspond to the original data (ortho-image) without any image transformation.

sults obtained:

It is interesting to draw the following critical insights from this experimentation (see Table 2). The first evidence links camera brightness to the ability to recognise the artwork. The Samsung A3 has Ground Sampling Distances (GSDs) twice the size of the others. Considering the same exposure parameters set manually on the three different cameras (ISO value and shutter speed), it can be concluded that Samsung A3 captures much more photons, which helps recognise features and link content. Although the One Plus 6 has two cameras that can create more detailed images, sometimes the image recognition algorithm can struggle with data overload. In this sense, a lower detail can lead to better recognition. So, it is not easy to find the best balance between the image characteristic, the acquisition condition and the camera's capability. The behaviour between the low and high recognition score target is relatively consistent. The OnePlus6 is the phone that can read transparencies better, but while it is the higher performing one, it loses in the distance test.

6. Street Art in Rome

Based on the experiences, an AR application has been tested on three case studies in Rome (Cavallari et al., 2022) with the figures of Anna Magnani (see Figure 9). The first example is a large-scale mural on a flat surface, created using the paint mural technique by Lucamaleonte. The work depicts

three different faces of the actress with two yellow-red roses, recalling the city of Rome, the Roma team, and the film “La rosa tatuata” (1956), directed by Daniel Mann (see Figure 9a). For these reasons, it was deemed appropriate to link a film clip to strengthen the cinema connection. The second case study is a stencil painting by Diavù made on a series of parallel surfaces belonging to a staircase (see Figure 9b). The work is titled “Anna Magnani - La Diva,” which does not reference a specific film (see Figure 9c).

For this reason, the example lends itself to the connection with an explanatory content of the representative model, underlying the realisation of the work by anamorphosis of decomposition. In this case, two additional elements do not favour artwork recognition. The anamorphosis requires seeing the artwork from a specific point of view and extracting the correct representation. It works both for the target acquisition and for the AR application. Besides, the multiple planes of the representation do not fit well with the camera's focal plane and the normal of the planes to fix the digital content. Therefore, the recognition process depends on the point of view, the number of projection surfaces, and the features in each plane (see Figure 10). The third and final case is a small flat surface affiches (poster) using the stencil technique. The work is by Lediesis, part of a series of stencil posters whose meaning is more linked to women and their capacities. Therefore, Anna Magnani's

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Jeeg Robot	Samsung A3														
	Samsung S4														
	OnePlus 6														
No Sur-render	Samsung A3														
	Samsung S4														
	OnePlus 6														
To Go Beyond	Samsung A3														
	Samsung S4														
	OnePlus 6														

Table 1. Results of the first trial: green images recognised, orange images recognised, but after some trials, red images were never recognised.

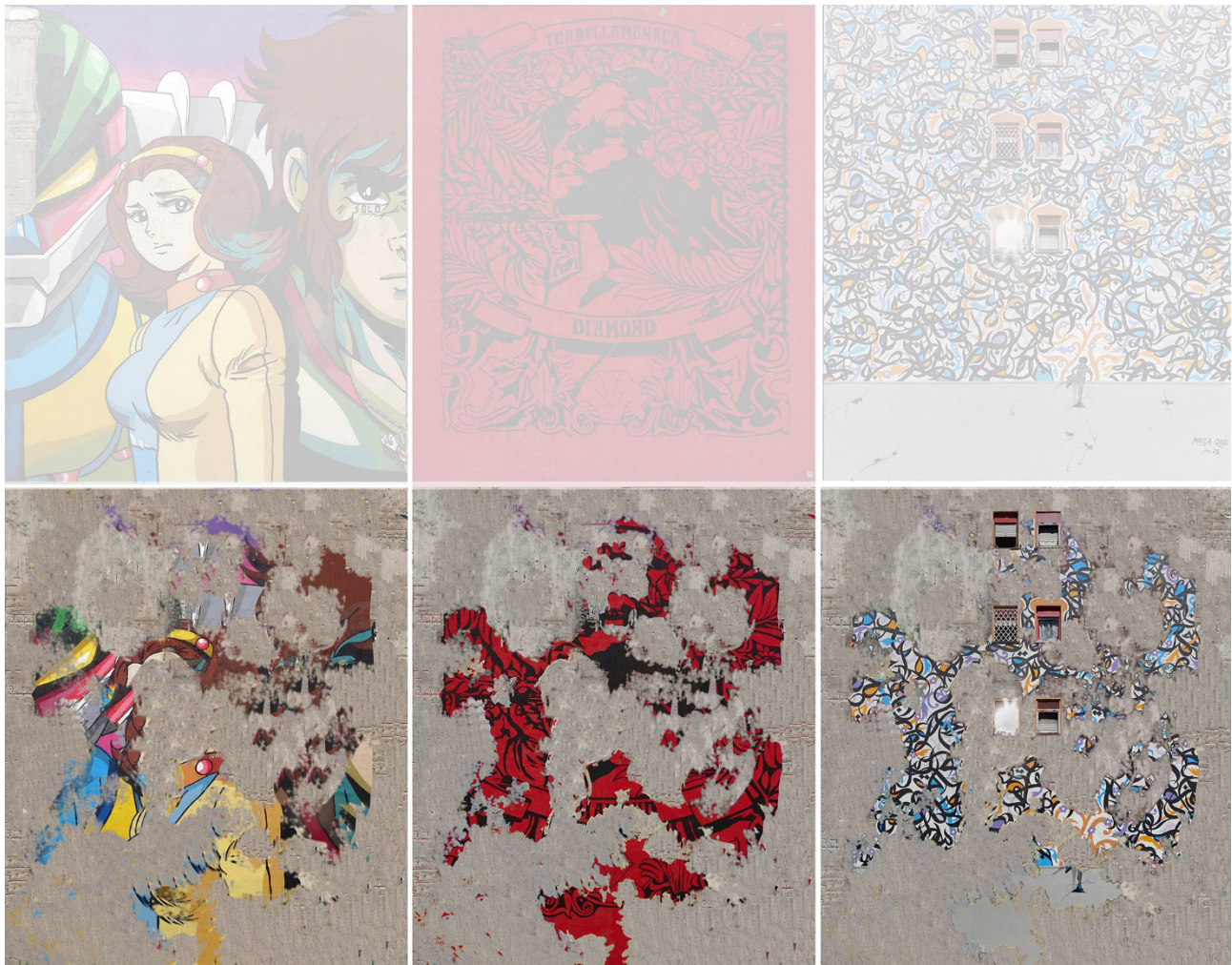


Figure 8. Hard-to-recognise images with AR. On the top row are the creations with 75% transparency, while on the bottom, many data lacks have been introduced, removing the original content.

	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m
Samsung A3								
GSD (mm)	0.50	1.01	1.51	2.06	2.52	3.02	3.53	4.03
Samsung S4								
GSD (mm)	0.27	0.54	0.81	1.08	1.35	1.62	1.89	2.16
OnePlus 6								
GSD (mm)	0.24	0.47	0.71	0.94	1.18	1.41	1.65	1.88

Table 2. Results of the second experiment: in green, the images recognised; in red, the distance at which it does not recognise the target; and in orange, the working limit of the smartphone.

image represents the universe of strong women. So, it was considered more consistent to link the work to an interview with the *Ladiesis*, explaining the general meaning of using female figures.

The experimentation revealed several bottlenecks in the application process. In the case study of *Lucamaleonte*, a determining factor was sunlight, which illuminates the entire surface at certain times of the day. This boundary condition has obliged to balance the AR video's transparency, preserving the balance between the work's readability and AR content (see Figure 11). *Diavù's* staircase showed the importance of identifying decomposition's correct vanishing point of the anamorphosis. It determines the correct legibility of the AR. The presence of numerous planes makes identifying the image by the camera complicated, so we simplified it by using the central part of the image as a target. At the same time, the presence of steps in the video's transparent background confuses the visualisation of the content, preferring a non-transparent visualisation. *Ladiesis's* artwork presented an obstacle that prevented the work from being read in its entirety. The contents have been presented without transparency, while the transition from nadiral to tangential makes the AR unstable.

7. Conclusions

The proposed research focuses on AR to enhance and understand Street art, suggesting a respectful digital-real relationship with the artist. It is critical to keep the democratic content and the possibility of non-durability of the work, suggesting a consistent interaction in a multi-platform open-source application. Besides, the image recognition approach establishes a direct relationship with the physical artwork, setting the digital function according to the art conservation. This passage preserves the direct link between the work and the digital content concerning the durability of the work. The art recognition highlights some bottlenecks given by the applied techniques, the external light conditions, and the shape in which the artwork is represented.

Anthropic or natural transformation of artworks, which can develop differently, introduces variation in the artwork's recognizability, as demonstrated in the experimental outdoor simulation. Even the working distance is not invariant for the readability of the artwork, which is mainly related to the sensor's sensitivity and the camera's characteristics. All these factors must be carefully evaluated concerning the boundary conditions of usability when designing an AR display system. For example, in the anamorphosis, recognition



Figure 9. Case studies analysed in the experimentation: a) Anna Magnani in Tiburtino III (*Lucamaleonte*), Anna Magnani. La Diva e la donna in Nuovo Mercato Andrea Doria (*Diavù*), Anna Magnani in Trastevere (*Ladiesis*).

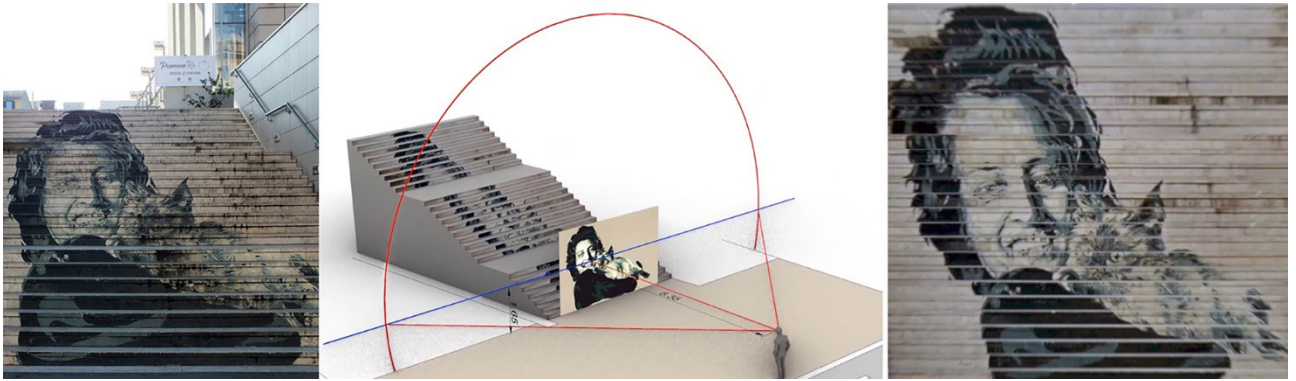


Figure 10. Photographed staircase (left), geometric-perspective scheme with vanishing point and projection of the plane onto the steps (centre), anamorphosis reprojected in original shape (right).

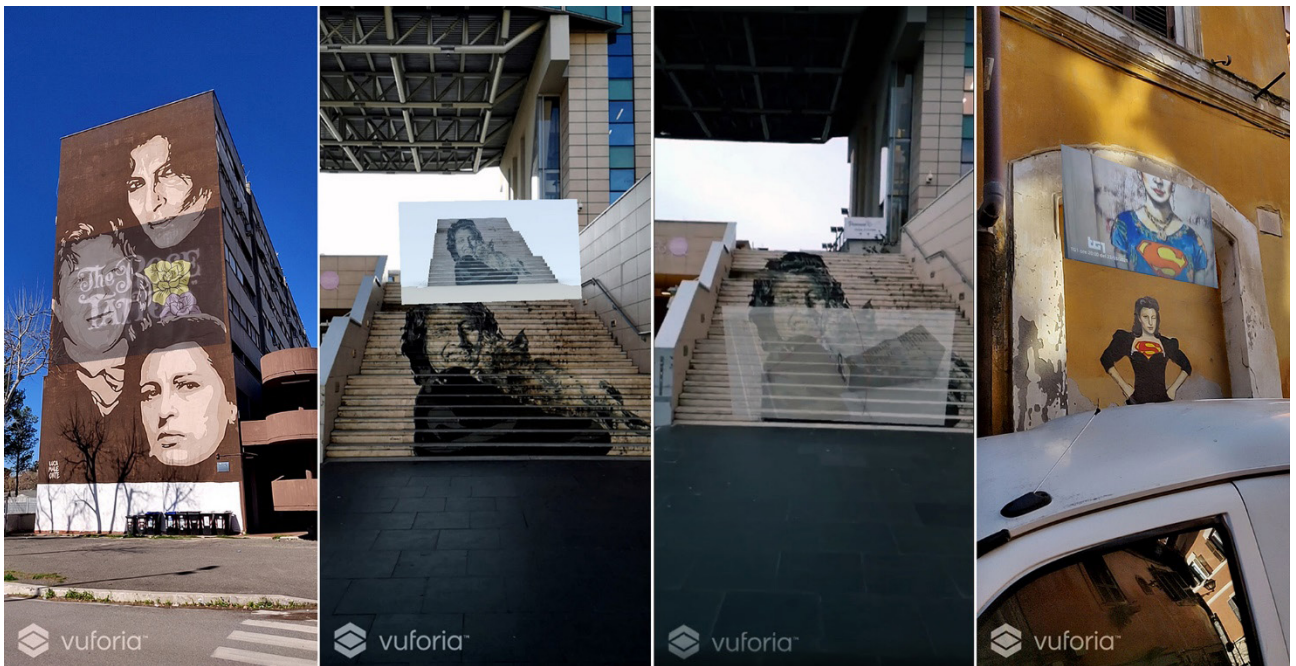


Figure 11. Experiments with AR in the three case studies with video in transparency (left), animation (the two images in the centre of the image composition), and top video (right) within Unity and Vuforia environment.

requires solving both the reverse perspective, looking for the preferred point of view and the mismatch in the recognition by the camera. This problem may change when dealing with works projected onto different (e.g., cylindrical) and complex surfaces. Finally, the AR content must enhance the work without hiding it, choosing the most suitable textual, multimedia, or 3D data. The content is strictly related to democratisation, iconicity, and target audience. AR in urban art can substantially contribute to fuelling the growth of this domain if designed according to a priority of content consistent with Street art. The experiment in the paper suggests a possible critical approach to the problem. Besides, the topic traces a research domain defined by a multidisciplinary connotation, opening new research scenarios.

Conflict of Interests

The authors declare no conflict of interest.

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