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Redefining Post-Natural Disaster Cultural Heritage Preservation: The AI Revolution in 3D Modeling and VR

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Introduction

Environmental anthropology offers a lens through which we can interpret natural disasters. These events challenge and reveal the fragility and resilience of cultures, especially when they teeter on the delicate balance between life and death. Today, due to the compounding effects of climate change and less-than-optimal governmental policies, the intensity and frequency of natural disasters have been on the rise. The period following these disasters, known as the recovery or post-disaster phase, is crucial for shaping societal and global memories. These memories will undoubtedly have a profound impact on future cultural constructions. Drawing upon the insights of Durkheim & Mauss in "Primitive Classification" (1903), where they emphasize the symbiotic relationship between nature (macrocosm) and culture (microcosm), (Orr, Lansing, & Dove, 2015) it becomes evident that events such as the Kahramanmaraş earthquake in Turkey are not only natural calamities. They also highlight the importance and implications of deliberate urban planning and societal organization.

Turkey's geographical position, straddling numerous fault lines, has made it vulnerable to catastrophic seismic activities throughout its history. On the 6th of February 2023, a tremor registering 7.8 on the Richter scale, the second most powerful ever recorded in the nation's annals, struck at 4:17 am with its epicenter located in Kahramanmaraş. (National Earthquake Information Center, 2023) Later in the day, at 11:34 am, another quake, slightly less severe at 7.7 magnitude, occurred.(Global Centroid Moment Tensor, 2023) These seismic events are the most powerful documented in the Levant fault zone.(Bilginsoy et al., 2023) The United Nations Development Programme (UNDP) reports document the profound impact of the earthquakes on Turkey's cultural heritage. Four UNESCO World Heritage Sites, 28 museums, and an additional 8,500 cultural properties were severely affected - comprising mosques, tombs, caravanserais, cathedrals, monasteries, castles, and traditional residences. An initial appraisal by the Directorate General for Cultural Heritage and Museums disclosed that 299 cultural assets were obliterated, 780 suffered significant damage, 718 incurred substantial impairment, and 3,392 were mildly affected.(United

Nations Development Programme, 2023) Turkey's rich cultural heritage is currently at risk due to the devastating seismic event, posing threats to both the region's sustainable development and global patrimony. The city of Hatay, located in the south and southeast regions and known for its abundance of ancient civilizations and cherished heritage, suffered the most severe consequences from the earthquake. Nearly all cultural heritage sites in Hatay faced extraordinary risk, with a significant portion reduced to rubble. Given these attributes, it is crucial to prioritize cultural preservation as an important aspect of rebuilding and restoring the city after such catastrophic events. The focus should not solely be on reconstructing physical structures but also on safeguarding the intangible heritage that defines Hatay's unique identity and resilience. The primary objective of this article is to investigate the amalgamation of Artificial Intelligence (AI) technologies and visual anthropology methods as practical tools for assessing, documenting, and

prioritizing preservation efforts for earthquake-affected cultural heritage sites in Hatay, Turkey, with a particular emphasis on acknowledging and integrating local cultural values and practices.

Chapter one delves into the transformative role of Artificial Intelligence (AI) in cultural heritage preservation and representation, charting its journey from the 1970s rule-based systems to its modern capabilities in 3D modeling, Virtual Reality (VR), and photogrammetry. The chapter underscores how the fusion of AI with 3D technology has redefined digital restorations, expanding from two-dimensional artifacts to intricate three-dimensional structures.

Chapter two introduces a cutting-edge technology named Neural Radiance Fields (NERF). This technology is utilized for scanning cultural heritage sites, effectively converting them into accurate three-dimensional models for Virtual Reality (VR) installations. The chapter comprehensively explains the NERF technology, including its operation, applications, benefits, and potential future enhancements. It also elaborates on the process of transforming these scanned models into immersive VR experiences, further enhancing our ability to study, preserve, and appreciate these cultural heritage sites. As the chapter concludes, it presents the cultural heritage scanning process results in Hatay, Turkey. Each scanning outcome is dissected and explained in detail, revealing the implications of these findings for the broader field of cultural heritage preservation.

Furthermore, the chapter explores the intersection between visual anthropology and contemporary technological advancements. Central to this discourse is motion interpolation, particularly its evolution with deep learning. This part critically assesses the potential of such advances for ethnographic authenticity in our digital era. Through the AI-powered Frame Interpolation software by Runwayml, a visual journey of Antioch's historical sites juxtaposes their past and present states. The narrative concludes by examining Antioch's post-earthquake transformations, emphasizing the poignant changes to landmarks.

Chapter 1

Presently, we are in an era where AI, a testament to human innovation, has begun to perform tasks typically reserved for humans, often with equal or superior results. This evolution challenges our perceptions of human uniqueness and highlights AI's learning capabilities, enabling it to perform complex tasks formerly exclusive to human entities.[1] Unimaginable in the mid-nineties, current 3D technology and virtual reality now support digital restorations extending beyond two-dimensional items like wall murals, mosaics, documents, and library materials. The scope has expanded to three-dimensional restorations, including sculptures, movable artifacts, and architecture. The increasing utilization of virtual reconstructions in scientific applications and dissemination initiatives—seen in exhibitions, museums, and archaeological sites—signals a new era. This large-scale adoption stems from the recent blending of media in digital applications. It merges various paradigms and languages from different domains, such as virtual reality, theatre, cinema, applied games, etc. This combination engages users and solidifies knowledge via a rich, impactful narrative and cultural experience.(Crawford, 2021) Virtual Reality (VR) and 3D modeling offer novel avenues for engaging with historical narratives. For instance, these technologies can be employed to digitally reconstruct historical sites, allowing individuals to virtually explore and experience these locations, gaining insights into their past.

Furthermore, they enable the creation of immersive and interactive narratives that breathe life into history in ways that traditional methods cannot. The extensive advancements in the AI industry have significantly impacted cultural sectors, particularly in the realms of cultural heritage restoration and preservation. AI is leveraged to automate and streamline the creation of 3D models, with algorithms analyzing 2D images or scans to deduce depth and produce 3D models. AI can also enhance these models by autonomously introducing intricate details, which would otherwise be challenging and time-consuming. The application of AI extends to photogrammetry, the process of creating precise measurements, maps, or 3D models from photographs. Machine learning algorithms can be trained to auto-detect and correct errors in the 3D models, effectively improving the accuracy and efficiency of the photogrammetry process. When combined with 3D modeling and photogrammetry, AI aids in reconstructing historical sites, artifacts, and events, allowing users to virtually explore these sites in a VR environment. This capability is particularly valuable for inaccessible sites no longer exist in their original form. AI's role in facilitating interactive and personalized learning experiences within VR is paramount. Natural language processing and machine learning contribute to creating intelligent virtual guides capable of real-time user interaction, a narrative adaptation based on user interest, and providing comprehensive information about specific artifacts or features.

Moreover, AI and VR contribute to documenting and preserving intangible cultural heritage like dances, rituals, or oral histories. AI's ability to analyze video recordings of these practices and create realistic VR experiences significantly aids in cultural preservation. In conclusion, AI considerably enhances VR experiences in the context of cultural heritage by improving the realism and detail of reconstructions, facilitating interactive learning experiences, preserving intangible cultural heritage, offering new insights through data analysis, and promoting accessibility and inclusion. Research in this domain encompasses a broad spectrum of topics, including the methodology of crafting virtual experiences, the impact of these experiences on our understanding of history, and the ethical considerations associated with digitally reconstructing historical sites or artifacts.

Digital humanities scholars contribute to advancing knowledge by delving into these areas, fostering a deeper appreciation and engagement with cultural heritage in the digital age. Digital humanities methodologies have introduced radical changes in the cultural heritage fruition. At the same time, the digital approach is profoundly changing historical research, which is the foundation of knowledge and understanding of cultural heritage. The most evident effect is a sort of ‘public use’ of the history(Calabi, 2013)The outputs of digital history are more accessible for the uses of preservation and, at the same time, for the audience of cultural heritage. For this purpose, cultural information becomes more understandable by linking data into space-temporal frameworks. (Tamborrino & Rinaudo, 2016; Münster et al., 2016) Knowledge of space and time provides a crucial empathetic understanding of the cultural heritage's essential records. Just as all natural resources are susceptible to human interventions, cultural resources are also vulnerable to climate crises, wars, natural disasters, economic downturns, and political instability. ‘One of the most fundamental principles to improve resilience for disaster management is locating and deploying the essential goods and equipment to the affected areas.(2023 ,Wu & Farazmehr)’ The advancements in contemporary technology allow us to comprehend the persisting d surrounding cultural heritages at risk and the challenges local communities face in making their voices heard—this innovative narrative and knowledge transmission challenges old and repetitive patterns of cultural understanding (see also Luig 2012). Virtual heritage does not merely represent a collection of objects but instead serves as a protector of the associated intangible heritage. Open-access, web-

based 3D modeling platforms dedicated to Cultural Heritage embody this approach. They do more than just digitally preserving and presenting cultural heritage; they foster global awareness, accessibility, and collaboration, bridging gaps between past and present, local and global. Their significance goes beyond their technical prowess; they are instrumental in democratizing access to cultural heritage and promoting scholarly collaboration and public engagement. As these platforms evolve, they will play an increasingly critical role in future collaborations within virtual heritage, fostering a global community invested in preserving and appreciating our shared cultural legacy.

Chapter 2

Neural Radiance Fields (NeRF) constitute a groundbreaking methodological approach to 3D scene representation and rendering, first elaborated in the seminal paper 'Neural Radiance Fields for View Synthesis' by Ben Mildenhall et al. At its core, the NeRF framework employs a fully connected neural network to map a given 3D coordinate and a 2D viewing angle to a specific volume density and RGB color, as seen from that particular viewpoint. Essentially, this innovative technique facilitates the synthesis of novel perspectives of a 3D scene based on a limited corpus of 2D images. In lay terms, NeRF employs neural networks to generate intricate 3D models of a given scene. Once adequately trained, the model allows new visual renderings from diverse viewpoints, enabling sophisticated 3D navigation within the scene.(Mildenhall et al., 2020) The implications of Neural Radiance Fields are manifold and span multiple sectors. In virtual and augmented reality, NeRF offers a pathway to constructing high-fidelity 3D environments, thereby elevating the immersive user experience. Within the field of photography and cinematography, it presents new avenues for post-capture 'reframing,' enabling viewpoint alterations after the initial capture. Furthermore, the film and animation industries stand to gain significantly, as NeRF could streamline the labor-intensive processes of 3D modeling and rendering, ushering in a new era of realism.

In my recent endeavor to reconstruct damaged cultural heritage sites virtually, I employed Luma AI. This technology entered the Neural Radiance Fields (NeRF) domain in 2022 and is accessible on both iOS and Android platforms. While the original intention behind NeRF was to synthesize novel viewpoints of a given scene, Luma AI's implementation allows for the volumetric representation to be transmuted into a 3D mesh. This offers a compelling alternative to traditional photogrammetry methods for 3D scanning. Recent advances in neural rendering, deep learning, and computation have made this vision a reality.

Additionally, the company has ventured into expanding its capabilities by integrating its technology with Unreal Engine 5 and incorporating Augmented Reality features, thereby enhancing the practical applications of NeRF technology. In a systematic endeavor to document and digitally archive the seismic impact on religious cultural heritage sites in Hatay, I conducted drone photography across four strategically selected towns. Each town, significant in its own right for the civilization and history of the city, was subject to at least one Neural Radiance Fields (NeRF) scan. My focus was to capture sites that had experienced significant structural damage. By employing NeRF technology, the digital scans serve as a temporal snapshot of the post-earthquake conditions, and these digital archives could inform future restoration efforts through innovative AI tools. During my fieldwork, I noted a prevailing concern among local inhabitants about the rapid and haphazard removal of debris, which they perceive as a loss of their cultural heritage. This underscored the importance of digital archiving as a conscientious approach to preserving the city's historic elements.

The religious cultural heritage sites included in this study are as follows:

- Habib-i Neccar Mosque
- Tokaçlı Virgin Mary Orthodox Church
- Antakya Greek Orthodox Church
- Iskenderun Saint Nicholas Orthodox Church
- Arsuz Saint Yuhanna Orthodox Church
- Samandag Greek Orthodox Church of Saint Ilyas

Fig.1Satellite map of the religious landmarks in Hatay

After uploading the drone footage captured in video format for Neural Radiance Fields (NeRF) scanning, I obtained images in my desired 3D, 360, and video formats. Utilizing the "Camera Path Editor" option in the object preview section, I can re-capture the video imagery from a first-person perspective. This feature allows us to closely document the cultural heritage sites captured with the drone footage, enabling us to conduct detailed videography. Mainly, I could showcase Habib-i Neccar Mosque's interiors in greater detail through this filming technique. As depicted in Figure 2, the collapse of the mosque's ceiling allowed me to capture the internal damage it caused. I recaptured this aspect by adding keyframes to the video and adjusting the focal lengths to get a closer view of the damage sustained. After generating new videos through keyframes for each scanned cultural heritage site, I adapted the content to a format suitable for Virtual Reality (VR) installations. I curated a sequence wherein viewers could engage with approximately 20-second videos for each heritage site. Before each video, I incorporated 3D mock-ups and provided brief informative overlays concerning each cultural heritage asset's historical context and current status. My overarching objective was to offer viewers an empathetic lens through which to perceive the toll exacted on the historical fabric of a city by seismic events. I aimed to facilitate this as a passive observation and an interactive experience, thereby deepening the viewer's understanding and emotional engagement with these sites' cultural and historical significance.

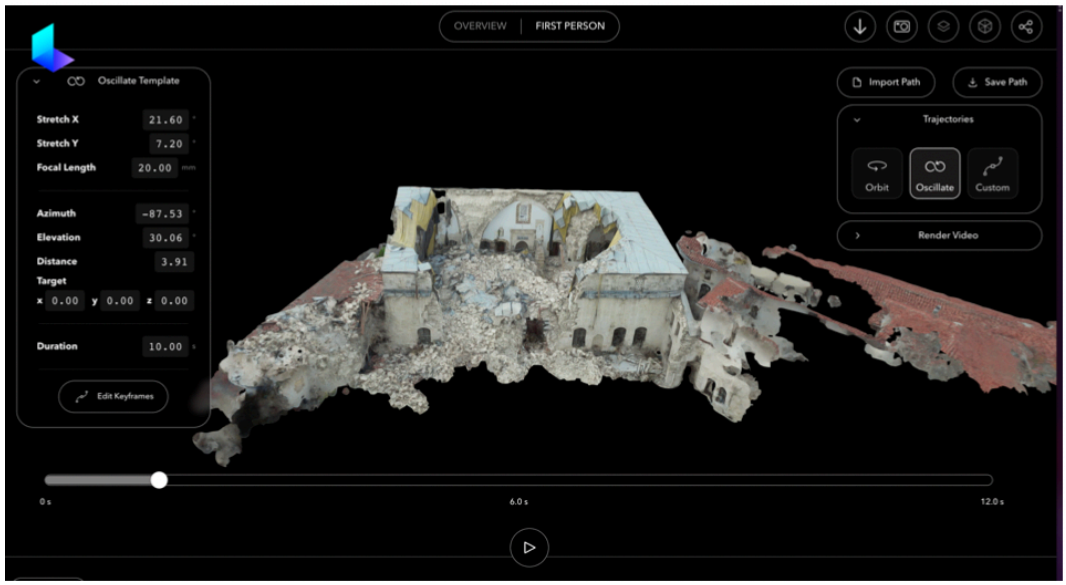

Fig.2 Habib-i Neccar Mosque with interactive 3D NeRF editing, Luma AI, May 2023

Fig.3 Habib-i Neccar Mosque with 3D object mesh, Luma AI, May 2023

Frame Interpolation

In visual anthropology, the technological nuances of video representation play a pivotal role in portraying ethnographic nuances and modulating audience reception. A pertinent example is motion interpolation, which, in its contemporary avatar, increasingly harnesses the power of deep learning algorithms. Traditional motion interpolation generates intermediate frames by analyzing pixel movement between sequential frames. However, with the advent of deep learning, models are trained on vast datasets to predict and produce more accurate and visually coherent interpolated frames, often surpassing traditional algorithmic methods in quality. The deep learning approach captures complex motions and scene structures, creating seamless visual continuity. Historically, the quest for fluid on-screen motion catalyzed the evolution of this technique. Yet, in anthropological settings, while the refined smoothness achieved through deep learning can make ethnographic sequences more palpable, it also raises concerns about the "soap opera effect," where visuals

become unnervingly lifelike, potentially jeopardizing the inherent aesthetics of the cultural content on display. Hence, while deep learning-enhanced motion interpolation holds promise for advanced visual fidelity, it also necessitates a critical examination of authenticity and the potential alteration of ethnographic veracity in our increasingly digitized era.

I employed the AI-powered Frame Interpolation software by Runwayml for the technicalities of frame interpolation. The software facilitates the creation of fluid video transitions from still images. The process encompasses three stages. Initially, a series of images are selected—congruent images enhance realism, whereas contrasting ones infuse creative flair. Subsequently, one adjusts settings such as clip duration (up to 10 seconds per image) and transition time percentage. The final stage involves initiating the generation process. Post-generation, one can refine the output through adjustment tools or revisit the selection of images.
My endeavor centered on capturing the transformation of Antioch's historical sites, juxtaposing their past and present states. I documented 360-degree videos of key historical streets—namely Kurtuluş, Saray, and their adjacent lanes—as well as the ancient bazaar. These videos were curated both for frame interpolation exercises and for an immersive VR experience.
To represent the "past" in my project, I employed photographs from Google Street View, tapping into the collective digital memory that such platforms offer. Initially, I scoured all available images on Google Earth Pro, emphasizing the clarity and accuracy of the shots, ensuring there were no camera glitches. Methodically, I scrutinized images uploaded over the years, cataloging each into my digital library. Once all images were identified, I embarked on the intricate task of shortlisting them for frame interpolation. I aligned select frames from my 360-degree videos with corresponding archived Google Earth images. Achieving congruence in angles and scenes was a challenging task, given the essence of effective frame interpolation hinges on the alignment of scene structures.
My project spotlighted Kurtuluş Street, notable not just for its distinction as the world's first illuminated street but also for its stark contrast after the devastating earthquake. One poignant capture was the commencement of Kurtuluş Street, near its intersection with the entrance of the Grand Bazaar. I synchronized a 2022 street image with a frame from my 360-degree video. The present-day imagery, characterized by the stark ruins of once-thriving buildings, rendered the frame interpolation particularly evocative.
Another significant capture was the Affan (İnci) Cafe establishment—a historic emblem of Antakya and a cherished locale for its inhabitants. The café, an architectural masterpiece, is the product of collaborative efforts between French architects and master stonemasons from Aleppo. It was meticulously designed as a stone tower, with its structural integrity upheld by two central pillars. During its construction, wells filled with water, remnants from the Roman era, were discovered. Situated on Kurtuluş Street within the Affan district, the café is colloquially referred to as the Affan Café.

Moreover, it has become synonymous with the dessert "Haytalı," a delicacy emblematic of Antakya, originating in Arab culture. The building sustained substantial damage following a significant earthquake, rendering it unusable. However, government officials have announced plans for its restoration. I sourced two images from 2019 and 2022 for this scene, complemented by a frame from my 360-degree video collection. Unfortunately, I could not access the inside of the botanical garden; therefore, I could not capture any videos from the inside.

In my latest exploration of Kurtuluş Street, I documented the Habib-i Neccar Mosque from two distinct perspectives utilizing the frame interpolation technique. Initially, I selected street view images from Kurtuluş Street that provided an overview of the mosque's architecture. Subsequently,

I integrated snippets from my 360-degree videos and transformed them using frame interpolation. Given that the mosque's main minaret had collapsed, I sought to recapture this area with a close-up perspective. The external walls of the mosque remained intact, but the ceiling had caved in. I believe this vantage point aptly documented the extent of the destruction. My documentation continued at the entrance of Saray Street, which is adjacent to the Asi River. My choice of this location was motivated primarily by the considerable damage it endured.

Additionally, the high resolution of street view images facilitated an accurate and efficient alignment with the scenes from my 360-degree videos. From there, I decided to capture the iconic Cumhuriyet Square of Antakya. Relying on street view, I could access images from 2019 to 2023. This time, I utilized only street-view images without incorporating 360-degree video footage. The sheer volume of available images from street view allowed a more detailed observation of the transformations over the years. Specifically, using the frame interpolation technique, I was keen to document the Council for Culture and Arts Center separately. Established in Hatay in 1927 by French architect Leon Benju and initially serving as a cinema hall adjacent to the Asi River, the building became an assembly house. Currently known as the Council for Culture and Arts Center, this historic tower has hosted numerous events. A pivotal moment in its history was the decision made here on July 5, 1939, for Hatay's annexation to Turkey. In 2019, the Hatay Governorate announced that the building would be restored to its original design and continue operating as a Cultural and Arts Center. Post-earthquake observations revealed that the building had collapsed entirely, and particularly the restored sections were unrecognizable.

Fig.4 The entrance of Saray Avenue with Frame Interpolation, RunwayML, August 2023

Watch: Antakya in Focus: 3D Heritage Sites & Quake Altered Scenes

Watch: Post-Quake Antakya: 360° Exploration (with VR glasses)

Conclusion

The examination of Hatay, a region known for its cultural and historical convergence, highlights the importance of understanding our past in shaping our future trajectory. In today's digital age, where fleeting interactions dominate, Hatay's complex histories serve as a poignant reminder to appreciate the intricate and human narratives that underpin historical progress. Due to its strategic location along major trade routes and fertile land, Hatay has historically been a melting pot of cultures, preserving its rich heritage. From an anthropological perspective, the region offers a vast research domain due to its continued coexistence of diverse religions and cultures. This harmonious blend of traditions is why the city is often called the "city of civilizations." The continuation of this harmony is closely tied to individuals' ability to freely practice their beliefs, with regular religious practices in their respective places of worship playing a crucial role in fostering a sense of belonging among members of different religious communities and ensuring their lasting presence in the region.

Throughout this project, a particular focus has been placed on Antakya, where the devastation has revealed extensive damage and destruction of historical streets and places of worship. As the city embarks on its reconstruction journey, accurate, archival documentation emerges as a crucial bridge between past lessons and future endeavors. One of Hatay's defining features is its longstanding tradition of diverse religions and cultures living harmoniously. This unique characteristic necessitates ensuring individuals can freely express and practice their faith. ’‘No map is complete without signs of habitation. Understanding vulnerability requires more than understanding societies’ past and present relations about disasters and development. Vulnerability is about people, their perceptions, and their knowledge. People’s ideas about risk and their practices about disasters constitute the sextant and compass with which they measure and chart the landscape of vulnerability.(2004 ,Hilhorst & ,Frerks ,Bankoff)’’

Stories bridge cultural artifacts and individual experiences, connecting them to broader social and political contexts. The temporal and spatial relationships within these socio-political matters emphasize the importance of historical narratives. In my project, I utilized Nerf technology for 3D scanning of worship places, aiming to create an archival record for future narratives. However, this technology may not be sufficient for restoration purposes. Restoration initiatives should ideally involve specialists in the field to ensure authenticity and should be carried out with the necessary permissions. Based on the data obtained, it can be deduced that the precision of Laser Scanning surpasses that of 3D Nerf technology in restoration endeavors. However, the ability of 3D Nerf technology to quickly provide detailed 3D videos and object visuals offers significant advantages for ethnographic narratives in visual anthropology. By utilizing this technology, I enhanced the visual perception of drone captures by converting them into interactive 3D visuals, allowing for reshoots. This enriched the VR integration process and provided a more comprehensive experience for viewers.

Introducing the viewer to the current state of historical streets and the grand bazaar through 360-degree VR cameras serves a dual purpose - it fosters an understanding of the conditions after the earthquake. It evokes empathy toward the magnitude of the destruction.

In light of the escalating severity of natural disasters and the ongoing climate crisis, there has been a noticeable expansion in the depth of environmental digital narratives. The utilization of digital scientific methodologies has brought about significant transformations in the field of historical research, which forms the foundation of our understanding and appreciation of cultural heritage. One notable outcome of these advancements is the increased accessibility of historical information

for conservation purposes and the wider population's interest in cultural heritage. By linking data to spatial-temporal frameworks, cultural information becomes more easily understandable. Therefore, in the immediate aftermath of an earthquake, it is my belief as an anthropologist that creating a digital archive is the most advantageous approach to bridging the gap between the past and the future.

Moving forward, the protection of Hatay's cultural heritage necessitates the consolidation of collective memories through various innovative methods of data collection. One of the most distressing consequences of the earthquake for the people of Hatay was the loss of memories. To address this, a collective memory museum should be established, incorporating contributions from local residents and integrated into the city's reconstruction efforts. Given Hatay's history of repeatedly rebuilding after major earthquakes, creating such archival records is essential for future generations. This archive should serve as a visual lesson to the world, highlighting the dangers of uninformed construction and the repetition of past mistakes. Using NERF technology, combining deep learning, augmented reality, and animation descriptions with the Unreal engine, can provide a distinctive and innovative narrative for promoting the city.

Following the earthquake, the devastation not only affected the city's physical infrastructure but also had a profound impact on its socio-cultural fabric. Technological advancements, particularly in fields like 3D scanning and visual anthropology, have played a crucial role in preserving and documenting the region's historical legacy. However, to fully harness the potential of these technological tools, it is important to view them not only as innovative gadgets but also as tools with ethical, cultural, and historical significance. The revival of the region and the preservation of its socio-cultural identity require collaborative efforts with local communities. Historic sites such as the Grand Bazaar and local producers are vital to the city's vitality. Their revitalization will significantly contribute to the community's economic, social, and cultural development and aid in the healing process following the disaster. This healing process should not be limited to physical reconstruction alone. Attention must also be given to the psychological and emotional well-being of the city's residents. To truly grasp the importance of cultural heritage and socio-cultural structures, listening to their stories and experiences is necessary. The traumatic effects of disasters can have long-lasting impacts on communities' recovery and rebuilding efforts. Therefore, a comprehensive approach that addresses the reconstruction of infrastructure and the community's spiritual and cultural rejuvenation should be adopted. Lastly, considering the possibility of future natural disasters, it is crucial to understand the vulnerabilities of cities that have historically experienced repeated destruction and reconstruction and to develop strategic measures to mitigate these vulnerabilities. This will ensure that cities are resilient in physical and socio-cultural terms.

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