Tree Mediators

Digital Narration of Arboreal Heritage

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Abstract. We present a methodology for digitally narrating the heritage of trees by integrating tangible and intangible elements into immersive virtual environments. Current methods for documenting tree heritage often focus on either the biological traits of a tree or its cultural aspects, with limited attempts to synthesize both. Our approach harnesses multimedia to reveal the many dimensions of a heritage tree, resulting in what we term a "Tree Mediator"—a dynamic, interactive model that bridges the ecological and cultural narratives of arboreal heritage. The methodology comprises five stages: tree selection, data collection, data processing, virtual environment development, and interactive tree narration. This framework incorporates tools such as 3D scanning, archival research, and gaming engine-based environments to create immersive, multi-dimensional representations of heritage trees. The methodology was tested on several heritage trees in a Mediterranean landscape, with three examples discussed in detail. The results demonstrate that the proposed integration of digital tools offers a novel way to document and experience the complex significance of heritage trees, fostering new modes of interaction with these living monuments.

Keywords. Tree Heritage; Immersive Environment; Digital Heritage; 3D scanning; Gaming Engine;

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1. Introduction

Trees are keystone ecosystems, embodying cultural and ecological heritage across diverse landscapes (Jones & Cloke, 2008; Lindenmayer et al., 2013). Veteran trees, in particular, serve as spiritual and cultural landmarks, enduring changing environments (Dafni, 2007; Roux et al., 2022). Often called "heritage trees" due to their size, location, historical importance, and religious associations (Ritchie et al., 2021), these trees are frequently treated as mere biological entities because traditional records struggle to capture their rich, intangible heritage (Jim, 2017). Limited methods of study have restricted our understanding of their pivotal role in environmental and cultural history.

There is a growing opportunity for new digital methods to study the layered significance of trees within cultural and ecological contexts. While recent studies emphasize the importance of digitally preserving tree heritage (Arthur & Ryan, 2024), archiving trees remains challenging due to the complexities of tangible (e.g., size, age) and intangible (e.g., symbolism, myths) information (Abbot, 2021). Current models often separate between ecological and cultural dimensions, lacking a comprehensive approach that integrates both.

This study offers a methodology to create a multi-dimensional virtual model that combines cultural, archival, and ecological elements of tree heritage. By leveraging digital tools, we explore through a design studio how virtual environments can serve as "Tree Mediators," enabling immersive experiences that convey heritage trees' aesthetics and cultural narratives. Our approach moves beyond biological or built heritage studies, employing interactive media tools to reveal the complex stories embedded within trees.

2. Literature Review

Heritage trees hold significant historical, cultural, and ecological value. Recently, Ritchie et al. (2021) proposed standardized criteria for identifying heritage trees, including factors like historical value, national interest, local significance, and botanical rarity. These criteria highlight arboreal heritage as a complex biocultural concept, where trees intersect with people, events, and policies, necessitating a revised 'tree sense' that captures their multifaceted meanings (Goldsmith, 2018).

Several methods were suggested for documenting tree heritage. Hou suggests curating historical texts to convey how trees become cultural heritage through poetics and memory (Hou, 2018). Hribar and Lisec use a GIS-based system to catalogue trees, integrating fieldwork and interviews (Hribar & Lisec, 2011). Rayn's approach includes a biocultural archive of multimedia materials to preserve botanical heritage, emphasizing storytelling's role in cultural preservation (Ryan, 2015). Galon conducted a 30-year survey that recorded tree age, dimensions, and historical stories (Galon, 2021).

Indeed, digital technologies have become crucial for preserving heritage trees by bridging ecological and cultural contexts. Techniques like LiDAR, photogrammetry, and 3D modeling provide precise digital representations, enabling virtual preservation and aiding ecological studies (Roudavski & Rutten, 2020; Guo et al., 2021). VR environments enhance public engagement by offering immersive experiences connecting users with heritage artifacts (Mann et al., 2023). Such technologies were

also shown to be effective as a supplement to the sensorial effect of being in a forest (Hejtmánek, 2022). Immersive digital storytelling offers new channels to disseminate heritage artifacts and allows new modes of engagement and agency over heritage (Benardou & Droumpouki. 2022).

However, a profound challenge remains in weaving together tree heritage's tangible and intangible layers into a unified experience. Our response is to harness multimedia to reveal the many hidden dimensions of a heritage tree, creating what we term a "Tree Mediator." This concept transforms the tree from a passive artifact into an active presence, a digital vessel that brings forth its layered histories, ecological significance, and cultural narratives, inviting viewers to engage with the tree's legacy in ways that transcend traditional representation.

3. Methodology

In this paper, we propose a design methodology for narrating tree heritage using a combination of environmental sensing, ecological data, multi-media archival materials, and real-time immersive renderings. Our study focuses on a selection of trees from a Mediterranean landscape, chosen for their historical, cultural, and ecological significance, foregrounding the political complexities inherent to this landscape.

The methodology consists of five stages, as shown in Figure 1: (1) Tree Selection: Trees are selected based on specific criteria (see Section 2). (2) Data Collection: Comprehensive data is collected, including 3D scans, archival research, and optional ecological data. (3) Data Processing: The 3D scans are processed into meshes or point clouds, and knowledge graphs are developed to map each tree's ecological, cultural, and historical aspects. (4) Virtual Environment Creation: A gaming engine combines the data and knowledge graphs into an interactive digital space. (5) Tree Mediator: The final product is an immersive, interactive virtual environment showcasing the multi-dimensional heritage of each tree. This environment is accessible either as a gaming experience on a personal computer or as a publicly displayed immersive installation.

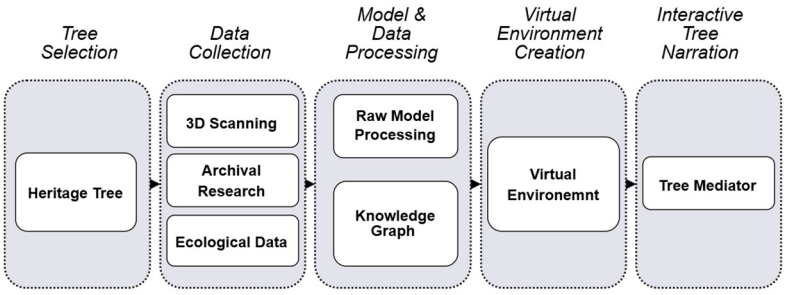
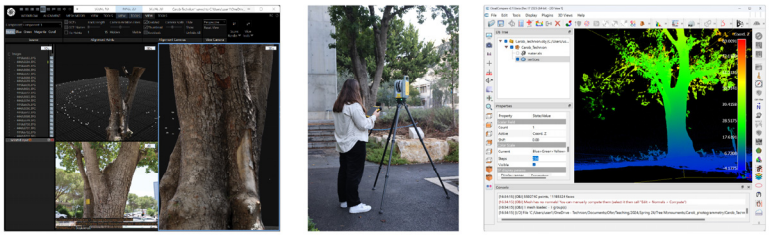


Figure 1. Workflow of the proposed methodology for narrating multi-dimensional tree heritage.



Photogrammetry *LiDAR Scanning* *Pointcloud processing*

Figure 2. Collection and processing of spatial data of heritage tree, including photogrammetry, LiDAR scanning and pointcloud processing.

3.1. DATA COLLECTION

The first stage of our methodology involves gathering detailed ecological, spatial, and historical data on each tree. Using photogrammetry and LiDAR, we generate accurate 3D models. RealityCapture (Version 1.4) processes approximately 200 images per tree for photogrammetry, while LiDAR scans are conducted with a Trimble X7. These scans are registered with Trimble Perspective (Version 3.1) and further processed in CloudCompare (Version 2.13.2) for final refinement. Figure 2 illustrates the process of gathering and processing such spatial data.

Additionally, archival research gathers historical records and narratives, incorporating local archives, reports, and oral histories to add cultural context to the 3D models. While beyond this paper's scope, future efforts could include ecological data collection (Matasov et al., 2020), using sensors for soil moisture, temperature, and tree physiology, as well as biodiversity surveys, to enrich understanding of each tree's ecological role and environmental interactions. Here, we also highlight that online sensors can be used to showcase the tree carbon uptake, water transport, and growth dynamics in real-time.

3.2. KNOWLEDGE GRAPH

Following the data collection, we suggest organizing the materials by creating a knowledge graph. These graphs map the relationships between the heritage tree, its surrounding ecosystem, the gathered archival data, and the cultural narratives associated with it. The schematic knowledge graph, as seen in Figure 3, illustrates how species and tree-specific traits, as well as ecological and cultural dimensions, are interconnected.

The relevance of mapping these elements as a network, drawing on Actor-Network Theory (ANT), lies in the ability to arrange archival and ecological materials alongside human and non-human actors, thereby constructing a non-hierarchical, distributed map. This approach allows the tree to be represented not merely as a static object but as a dynamic entity with enhanced agency within its environment and cultural context, echoing discussions on the agency of trees (Jones & Cloke, 2008). Such knowledge graphs can serve as a blueprint for developing an immersive virtual environment that encapsulates the multi-dimensional heritage of the selected tree.

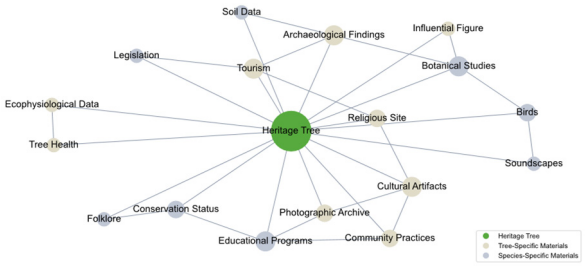


Figure 3. Schematic knowledge graph of a heritage tree, featuring tree and species-specific nodes.

Figure 4. Selected heritage trees from a Mediterranean landscape discussed in this study.

3.3. VIRTUAL ENVIRONMENTS CREATION

To capture the complex interplay of natural and cultural significance inherent in heritage trees, we propose utilizing advanced gaming environments such as Unreal Engine or Unity to create immersive virtual spaces. These platforms support real-time, interactive renderings, enabling the integration and layering of diverse data types—ranging from images, videos, and text to sound and material textures. Additionally, cinematic techniques, including dynamic camera movement, lighting, and colour schemes, can be employed to introduce an atmospheric dimension that heightens the aesthetic and emotional engagement of the virtual experience.

Through these tools, we develop highly detailed virtual twins of the heritage trees, allowing users to explore them in an interactive, immersive setting. This approach goes beyond mere accurate visualization of the tree, providing an experience conveying the trees' multi-dimensional heritage from ecological and cultural perspectives.

4. Case Study: Trees in a Mediterranean Landscape

Trees in Israel hold profound significance, acting as mediators between the natural environment and the cultural landscape. They embody the country's rich history, territorial complexities, and spiritual beliefs, reflecting how humans interact with and perceive the natural world. In this study, we examined a variety of nine trees, as seen. Each tree was selected by students, according to cultural, territorial, or symbolic

importance, to showcase the multi-dimensional heritage they embody, integrating ecological, historical, and cultural narratives specific to their respective regions. In this paper, we discuss the creation of a Tree Mediator for three trees shown in Figure 4: a Mount Tabor Oak (Quercus ithaburensis) located at the lower Galilee near Sakh'nin; a Mexican Fan Palm (Washingtonia robusta) avenue located in Zikhron Ya'acov; and a Chinese Banyan (Ficus macrocarpa) in Nazareth.

4.1. MOUNT TABOR OAK, SAKH'NIN, GALILEE

The Mount Tabor oak (*Quercus ithaburensis*), known for its resilience and longevity, stands in "Al Mal", an agricultural area in lower Galilee, Israel (32°28'24.28"N, 35° 0'18.02"E). The area name, according to local community attestations, "The Land of the Oaks", reflects the tree's former abundance, now diminished due to landscape transformations stemming from territorial and political battles. This oak serves as a witness to a complex, contested history.

Narrating the heritage of this oak requires a multi-faceted approach. Data collection included resident interviews to understand the oak's historical role, and archival research, using records from the British Mandate and Israel to document landscape changes. In addition, policies for preserving oak trees led to the tree being supported and cared for by local authorities. A knowledge graph was developed to map the intricate network between the oak, the agricultural community, and policies that reshaped the landscape on the one hand and preserved the oak on the other hand.

In this case, the virtual environment presents the oak in contrasting states: one reflecting historical impact, the other showing the disconnect between the region's name and its present state. This dual representation encourages reflection on the oak's role as a symbol of resilience amidst shifting landscapes.

4.2. MEXICAN FAN PALM, LANGA ESTATE, ZIKHRON YAACOV

A second case study is the Mexican Fan Palm (*Washingtonia Robusta*) Avenue in Zikhron Ya'akov (32°34'30.54"N, 34°56'56.80"E), a historic boulevard planted in 1912, stretching 60 meters towards the Langa Estate. Despite its partial abandonment and the loss of some original trees, the avenue's historical and cultural significance endures. Figure 5 illustrates the creation of a Tree Mediator for the Mexican Fan Palm Avenue at Langa Estate.

This case focuses on tracing the plantation of the Mexican Fan Palm, deliberately chosen to line the avenue for its resilience and grandeur. Introduced in the early twentieth century for decorative purposes by Dr. Aharon Aaronson, a world-renowned botanist, the palm has since been reclassified as an invasive species by the Israel Nature and Parks Authority. Nevertheless, the avenue's heritage remains deeply intertwined with Zikhron Ya'acov's development and the broader narratives of Jewish settlement in Israel, revealing the shifting ideologies that shaped the country's landscapes.

Data collection involved LiDAR scanning to capture the spatial dimensions and condition of the remaining palms, alongside archival research to uncover historical records, photographs, and narratives tied to the site. This data was compiled into a

Figure 5. Development of a Tree Mediator virtual environment for the Mexican Fan Palm Avenue at Langa Estate, Zikhron Ya'akov, following the proposed multi-stage methodology as outlined in section 3. Illustrations by students Tair Shekel and Tal Hofman.

knowledge graph mapping the avenue's transformation and its connections to the community and key historical figures (Figure 5). An immersive virtual environment was developed, allowing users to walk through the avenue's history, layered with archival documents, soundscapes, and architectural plans. By digitally reconstructing its past and present, this experience highlights how heritage trees like Washingtonia Robusta both shape and reflect the evolving landscapes they inhabit.

4.3. CHINESE BANYAN, MARY'S WELL, NAZARETH

A third case study is the Chinese Banyan (*Ficus Macrocarpa*) in Nazareth, also known as the Indian laurel fig, standing near Mary's Well (32°42'22.27"N, 35°18'5.42"E), a site of religious significance in Christianity. While its exact introduction is unknown, it is an exotic species that provides shade in urban contexts across Israel. Though beneficial for shading, its robust roots can damage infrastructure and historic sites (Jakoby et al., 2021).

This case examines the Ficus's journey from its tropical origins and its implications for the surrounding ecosystem and historical structures. The tree's significance is largely tied to its location—without proximity to the well, it might not receive the same attention. Simultaneously, it offers shade and shelter from the harsh Israeli sun, reinforcing the site's role as a gathering place. In this way, the tree integrates into the ecological, social, and cultural dynamics of the area, intertwining its natural heritage with the site's historical and spiritual importance.

The virtual environment digitally reconstructs the site, illustrating the ongoing interaction between the Ficus and Mary's Well. It contrasts the current environment with a hypothetical scenario without the tree, encouraging reflection on invasive species and their impact on historically significant landscapes.

5. Discussion

In this paper, we describe arboreal mediations that are brought to light through a methodology that employs a suite of digital and virtual tools, allowing for a multi-dimensional understanding of tree heritage. These tools, including 3D laser scanning, photogrammetry, knowledge graphs, and immersive virtual environments, enable researchers to capture the intricate details of a tree's physical structure and its surrounding environment, while simultaneously layering historical records, cultural narratives, and symbolic meanings onto the digital representation.

Altogether, this approach allows for the creation of "Tree Mediators," digital representations that go beyond simply documenting a tree's physical characteristics, revealing the complex network of relationships that connect trees to human history, cultural practices, and ecological processes. The methodology employed in these case studies demonstrates the power of digital tools to uncover the multifaceted roles trees play as mediators between nature and culture, fostering a deeper appreciation for their significance as living archives and dynamic participants in the human experience. The notion of "tree architecture entanglement" echoes the nature-culture entanglement as it underscores the intricate interconnection between a tree's physical structure and its surrounding environment, including human influences. Tree architecture entanglement recognizes that a tree's growth and development are not solely determined by genetics but are shaped by ongoing interactions with both biotic and abiotic factors, encompassing cultural practices, historical events, and human interventions (See, for example, Bachar et al., 2020). The projects exemplify the merging of nature and culture in a heritage site. Tree architecture entanglement reveals how a tree's physical form becomes a living archive of its interactions with the environment, including human interventions, highlighting the inseparable link between natural and cultural heritage.

6. Future Work

Virtual Reality (VR) presents a promising tool for immersive engagement, as seen in Figure 6. It allows users to experience trees at scale and appreciate their ecological roles. Future work could also incorporate perspectives from non-human tree users, such as mammals, birds, and insects, for a holistic view of tree heritage. Additionally, a validation phase will examine how individuals react to VR experiences, focusing on empathy and engagement levels.

A key aspect of future research will be evaluating the effectiveness of "Tree Mediators." This will involve tracking user engagement, assessing knowledge transfer through surveys, and analyzing emotional responses. Comparative studies between traditional documentation and immersive storytelling will help refine the methodology and determine the most impactful techniques for representing tree heritage.

Another important direction is integrating Tree Mediators into larger spatial information systems such as GIS and City Information Systems (CIS). This will enhance accessibility, support conservation planning, and facilitate community engagement. By embedding digital tree heritage within these frameworks, the approach can be scaled beyond individual case studies to broader urban and ecological applications.

Figure 6. Early experimentation with VR Tree Mediators allowing for immersive engagement with a heritage tree.

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