UnFrame: An Augmented Reality Narrative on the History and Possible Future of North American Timber Framing

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Abstract. *UnFrame* was an augmented reality (AR) exhibition on the history of timber framing in the Northeastern part of North America. In this region, timber has been a primary building material for millennia. The Hodinǫhsǫ́:nih (Six Nations Iroquois) constructed semi-permanent domestic longhouses from the trunks, branches, and bark of several locally available tree species. The *UnFrame* exhibition presents different periods of timber construction through an interactive AR exhibition to reflect and initiate conversations on the present timber industries, and their utilization of varying timber species, from architectural scales to a select series of details. With a focus on the Hodinǫhsǫ́:nih longhouse, this research paper presents the materials, equipment and methods necessary to construct the outdoor, public exhibition. The *UnFrame* exhibition is intended to be an educational tool representing and communicating these various timber material histories.

Keywords: Augmented Reality, AR exhibition, AR narrative, Timber Framing Histories, Interactive AR

1 Introduction

Increasingly, museum and exhibition designers have employed digital curators, artists, and programmers to develop new methods of augmented reality (AR) for art and curation (Marques & Costello, 2018). AR is a blend between real-world environments and context-based digital information (Sommerauer & Müller, 2014). Presently, AR virtual environments are made visible through mobile devices or head-mounted displays (HMDs). Compared to physical exhibits, AR benefits artists and curators to virtually exhibit large, full-scale, architectural constructions that would be too costly or difficult to physically display in a museum (Okada et al., 2015). Currently, AR is used by a number of museums and galleries throughout the world to help develop visual narratives on historic events and accurately re-represent historical artifacts that are only part of an original whole (Jin et al., 2022; Keil et al., 2013). However, many of these exhibits require the use of HMDs to experience the exhibit (Apostolakis et al., 2020; Muséum Nal Hist Nataurelle, n.d.), which are both expensive and often limit the amount of time visitors can view the exhibit. Alternatively, AR exhibits curated through mobile devices can be more accessible to the local public. As with HMDs, AR through mobile devices can offer a number of interactive experiences such as: visual overlay between virtual and real objects, audio storytelling, and motion detection. As an example, the CHESS project at the Acropolis Museum in Athens, Greece employs AR audio and visual interactions through mobile devices to provide its visitors with "personalized interactive storytelling experiences" linked to the museum's exhibits (Keil et al., 2013). CHESS explores the effects of embedding a museum's written histories into/onto the physical sculpture within the museum through an AR application. At the Bone Hall in the Smithsonian, virtual reconstructions of full-scale vertebrates were exhibited with mobile AR devices (Marques & Costello, 2018). Museums such as the National Gallery in London have used AR applications to digitalize art "on the streets" for non-museum goers (Fowler, 2021).

The *UnFrame* exhibition (Figure 1) was an interactive AR exhibition on the history of local timber construction situated on the Arts Quad at Cornell University, on the dispossessed land of the Gayogo̱hó:nǫˀ (the Cayuga Nation) (American Indian and Indigenous Studies Program, 2021) - The indigenous words in the paper are all rendered in the Gayogo̱hó:nǫˀ (Cayuga) language, reflecting the fact that the *UnFrame* exhibition is located on dispossessed Gayogo̱hó:nǫˀ territory. The intention of the exhibition was to develop an engaging, interactive AR environment to communicate pre-colonial, colonial, and post-colonial methods of domestic timber construction in the northeastern part of North America.

Figure 1. *UnFrame* Augmented Reality Exhibition

The research presented uses AR to visually articulate how a Hodinǫhsǫ́:nih longhouse might have been constructed along with a platform framed house and several virtual trees that describe the *Unlog* method (Lok et al., 2023), an experimental method of timber framing. Domestic longhouses were constructed by the Hodinǫhsǫ́:nih (Six Nations Iroquois Confederacy) in what is now central and western New York State. The Gayogo̱hó:nǫˀ are one of the member nations of the Hodinǫhsǫ́:nih, which can be translated literally as “people of the longhouse” (Froman et al., 2002:xi). This paper will describe the materials, equipment, and methods used to construct the AR exhibition, through the design of the 1:1 scale longhouse and associated details. The AR longhouse exhibits three distinct tree species; this paper also presents the results of testing a) exterior and interior representations of these tree species; b) different ways to communicate the location of details; c) various methods to interact with these details; and d) methods of illustrating the tree species as 3D virtual details. The *UnFrame* exhibition not only uses AR to communicate histories of timber material construction, but also provides a location for people to engage and interact with these histories collectively.

2 Methods

The *UnFrame* augmented reality (AR) exhibition tells the history of domestic timber framing innovations in the Northeastern region of North America. The exhibition includes a series of graphic panels (Figure 2) that explain the construction of a typical Hodinǫhsǫ́:nih longhouse, outline a brief history of colonial and post-colonial timber framing practices, and describe the methods used to construct the *Unlog Tower*. The AR 3D user interface (3DUI) exhibits a full scale, virtual reconstruction of a longhouse, a platform framed house, and four trees that illustrate the *Unlog* method (Lok et al., 2023) (Figure 3). The purpose of the exhibition was to use these various construction methods to describe varying efficiencies of timber material use in each historical period, at scales ranging from the full building to the detail level. The exhibition encourages users to engage with the details through an interactive notation without prescriptive audio narratives.

Figure 2. Exhibition panels with QR code panel

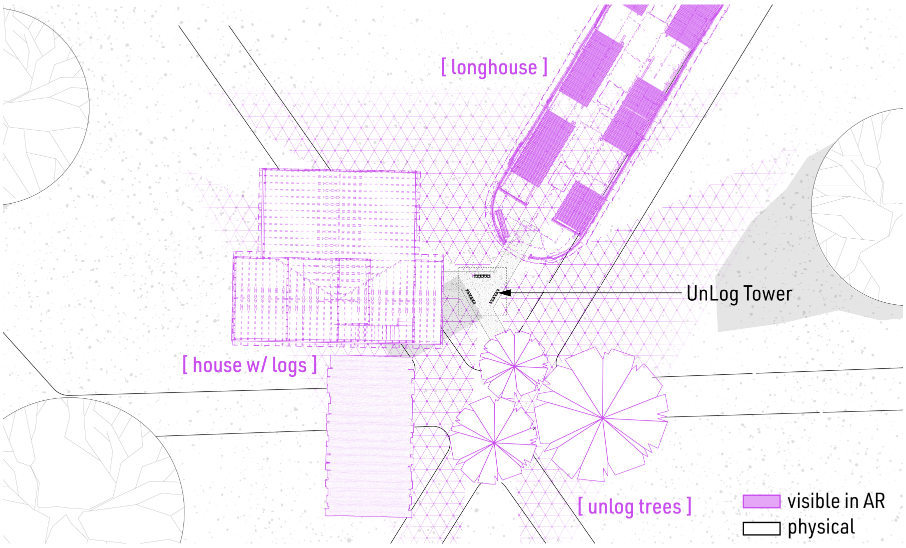

Figure 3. Plan of Augmented reality exhibition

Housed within the *Unlog Tower* at the center of the Cornell Arts Quad, the *UnFrame* exhibition is a public space open to students, faculty, staff, and visitors, all of whom have access to the local Wi-Fi networks. Connection to Wi-Fi is imperative to download, locate, and view the AR exhibition, using QR codes in conjunction with the *Fologram* mobile app (Figure 2). *Fologram* is an interactive AR and Mixed Reality software plug-in for *Rhino3d* and *Grasshopper* (Fologram Pty Ltd, 2021; Robert McNeel & Associates, 2022; Rutten, 2022).
Instructions for how to interact with the AR exhibition were printed on transparency paper and placed along with the other exhibition panels (Figure 4). In order to interact with the exhibition, users are prompted to download the *Fologram* app on any mobile device and then connect to the Wi-Fi network. Once connected, they scan the first QR code to access the digital model, and then place it in the correct physical location by scanning the bottom/second QR code. In order to run the studies described in the following sections, two files were set up on two different computers (Figure 4). The first computer (the Visitor Front-End) was used to run the exhibition file constantly so that users could interact with most of the exhibition as soon as the *Unlog Tower* was completed. The second computer (the Developer Back-End) was used to run the "work-session file." Within the work-session file, the files associated with methods 2.1, 2.2, and 2.4 could be quickly linked into the work-session file without having to change or alter the "digital model QR code" or the "location QR code." The tests for method 2.3 required more advanced features for direct user interaction with select details. Consequentially, the files associated with method 2.3 had to be directly imported into the "work-session file" so that the materials could be correctly referenced between the *Grasshopper* and *Rhino 3d*.

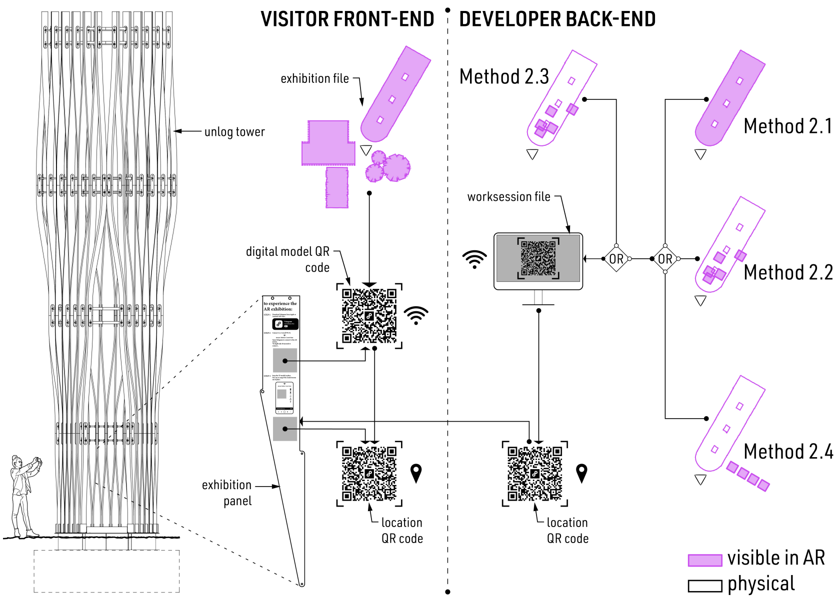

Figure 4. Workflow to sync digital geometry with exhibition**.**

2.1 Tree Species Display

Compared to the platform framed house and the unlogged trees, the AR longhouse contains the most diverse set of timber species. The first experiment was set up to visually render the materials of the longhouse in a way that illustrated the diverse set of tree species involved in the longhouse's construction, with a secondary goal to communicate the multi-family spatial layout of the longhouse. Three primary tree species were displayed in the longhouse AR exhibition's design: elm for the bark sheathing, cedar for both the vertical and horizontal posts and beams, and hickory to lash the cedar timbers together (M. Galban, personal communication, 2022). However, the lashing detail is only exhibited in select details to reduce the file size. Traditionally, the vertical cedar posts on the interior are larger than those on the cedar timbers running horizontally or those on the exterior (Jordan, 2008; Snow, 1995). To make this distinction, the cedar elements were represented through three different hues or saturations; thick posts would be the darkest and the secondary and tertiary timbers would be progressively lighter. On the exterior of the AR longhouse, 6 material schemes were selected (Figure 5).

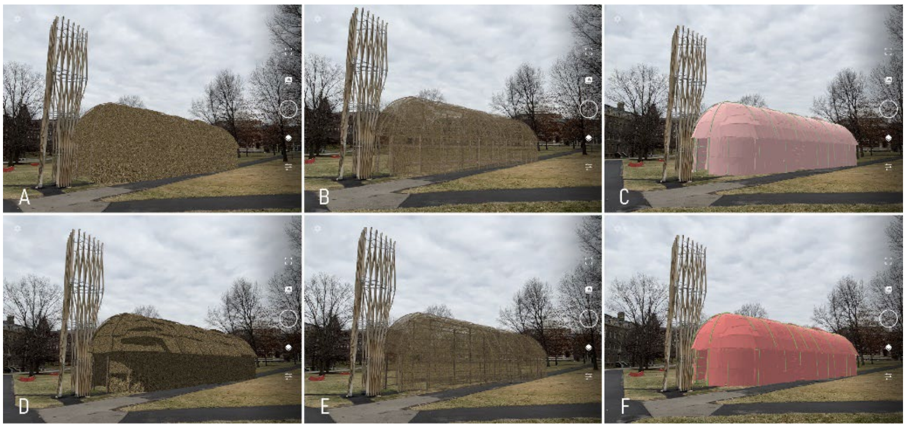

Figure 5. AR Longhouse exterior perspective: **a)** all opaque materials without shadows; **b)** translucent elm bark material without shadows; **c)** desaturated colors without shadows; **d)** all opaque materials with shadows; **e)** transparent elm bark material with shadows; **f)** saturated colors without shadows.

The same set-up can be seen in the interior perspective of the AR longhouse (Figure 6). The AR longhouse without shadows and all opaque materials is illustrated in Figures 5a and 6a, and with shadows in Figures 5d and 6d. Because the opaqueness of the bark material appeared to separate the user from the rest of the physical environment, Figures 5b, 6b, and Figures 5e, and 6e show a test using a 70% opacity of elm bark material without and with shadows respectively. In each of these tests, the stone on the ground is rendered with a gray material. Finally, Figures 5f and 6f illustrate each material with a unique color that has full saturation while Figures 5c and 6c use same material colors with 28% saturation of the materials used in 5f and 6f. By representing each tree species through distinct colors (as opposed to representing the natural materials) it more clearly separates the species from one another. Ultimately, the material tests with the transparent elm bark allowed the longhouse to read alongside the surrounding physical environment while showing some material contrast between species when the shadows were turned off (Figures 5b and 6b). An additional test was done to illustrate the elm bark material through lines based upon the mesh edges of the elm bark digital model, but the file size was 20 times that of the mesh only files. Consequentially, the mesh edges study was not further investigated.

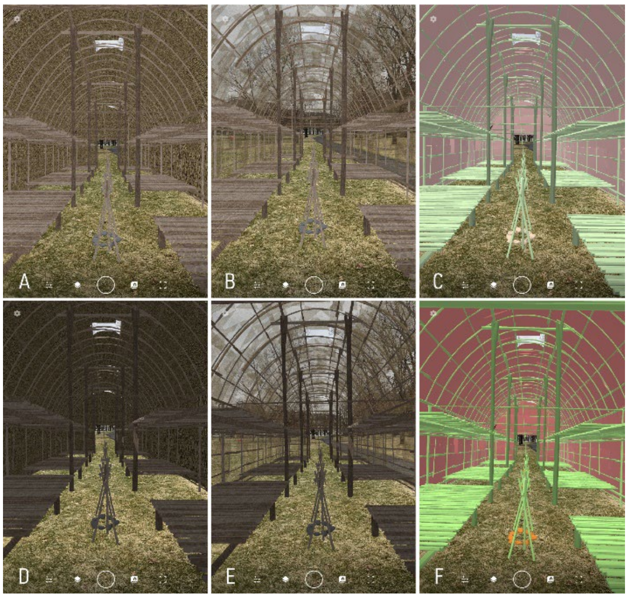

Figure 6. AR Longhouse interior perspective: **a)** all opaque materials without shadows; **b)** transparent elm bark material without shadows; **c)** desaturated colors without shadows; **d)** all opaque materials with shadows; **e)** transparent elm bark material with shadows; **f)** saturated colors without shadows.

2.2 Isolated Detail in Location

The various material of the Hodinǫhsǫ́:nih longhouse were more completely understood through details, which not only illustrated the use of hickory as a third tree species, but also demonstrated the highly efficient structural connections within the longhouse. The second method evaluated 4 different strategies to view select details separate from the overall geometry (Figure 7). Figure 7a illustrates 5 different details trimmed from the overall geometry, while 7b shows a box around the detail. Finally, Figures 7c and 7d display volumetric building notation around the select details with and without a translucent box respectfully.

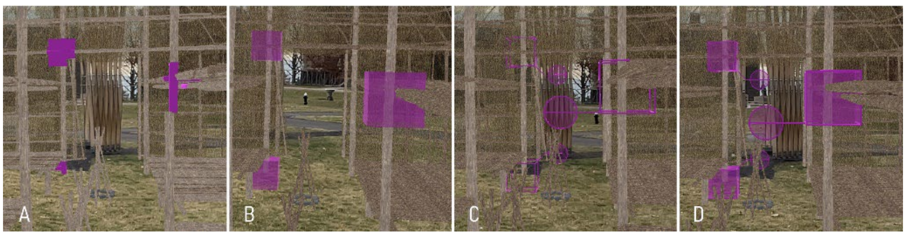

Figure 7. Isolated Detail in AR: **a)** detail color change; **b)** bounding box around detail; **c)** line notation adjacent to detail; **d)** bounding box with line notation.

2.3 Isolated Detail in Quick View

One of the goals of the exhibitions was to make the selected details of the longhouse engaging for the user to interact with, without cluttering the digital space. Each detail numbered 1-5 (Figure 8a), could be turned off or on in the layer management selection (8b) or selected with a parametric slider (8c); alternately, the user could tap the detail notation on the screen of their mobile device to display the detail (8d). The layer selection method had two disadvantages: first, the layer order between the mobile platform and the digital file did not match and second, users could turn layers off and on in the digital file, affecting the experience for subsequent users. The slider selection and the tap selection methods allowed multiple users on the platform to select any detail independently of the other users' selections, though other users could see each other's active detail selections. Additionally, in both the slider and tapping test, the selected detail would automatically be toggled off once the user closed the mobile app. Between these two methods, we concluded that the tap method would be more intuitive and engaging for the users.

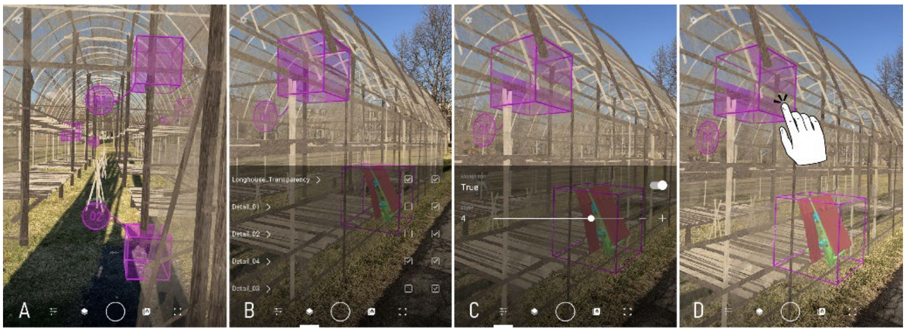

Figure 8. Detail Selection in AR; **a)** view of isolated details, **b)** detail selection by layer change, **c)** detail selection by interactive slider, **d)** detail selection by finger tap on mobile device.

2.4 Detail Material Display

As previously mentioned, Hodinǫhsǫ́:nih longhouses used three different tree species for construction. For the selected detail, Detail_04, the three timber species were rendered with 3 different materials (Figure 9). The first test illustrates the use of all opaque natural materials to render the detail (Figure 9a, 9e); the second test illustrates the use of a transparent elm bark material and opaque cedar and hickory materials for their respective geometries. Figure 9c and 9g illustrate the use of desaturated colored materials to articulate each tree species while Figures 9d and 9h use fully saturated colored materials. The saturated rendering method seemed most appropriate to articulate the different tree species as the materials were in high contrast to the rest of the AR exhibition and the surrounding physical environment, allowing the user to better articulate the distinction between all three tree species as compared to the material section in Method 2.1. The hickory lashing (cyan in Figure 9h) was modeled in *Rhino3D,* with *Kangaroo 2,* live-engine physics solver for *Grasshopper* (Piker, 2013), to tighten the curves of the lashing around the log meshes.

Figure 9. Detail Selection in AR **a, e)** all opaque natural materials, **b, f)** transparent elm bark material, **c, g)** desaturated materials, **d, h)** saturated materials.

3 Results and Discussion

The intention of the AR exhibit was to communicate different methods of domestic timber construction and through this visual communication, provoke conversations on the efficiencies and waste produced through timber construction. Compared to platform framing method and the *Unlog* method, the investigation into the Hodinǫhsǫ́:nih longhouse displayed in the *UnFrame* exhibit relied on the interpretation of written historical observation, research by archeologists, and communication with curators and local specialists. The platform framed house, a predominant construction method today, exhibited 68 tree logs stacked next to the house. Each log with roughly 16” diameters and at least 12’ in length, a standard logging size for industrial sawmills in this area. Based upon standard sawmill practices, it was estimated that 68 logs of the specified dimensions would be required to construct a house similar to the virtual house exhibited (Figure 10a). Finally, the virtual trees displaying sections of trunks that used *Unlog* method were intended to be a complementary reading of the *Unlog Tower,* tying board to the log, the log to the tree, the tree to its context (Figure 10b).

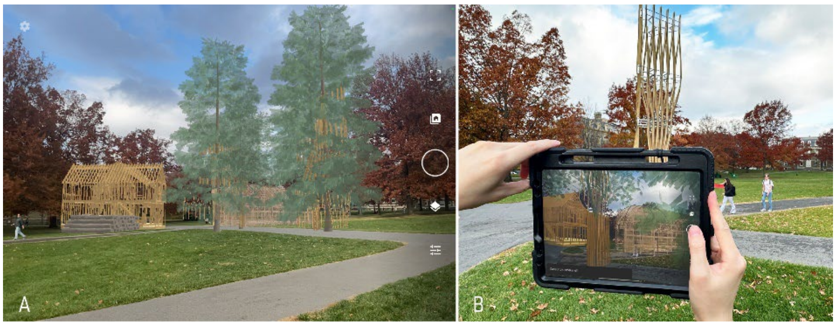

Figure 10. Perspective of *UnFrame* exhibition: **(a)** platform framed house with logs and *Unlog* Trees as viewed a mobile device, and **(b)** perspective of the AR exhibit near and the *Unlog Tower.*

The *UnFrame* exhibition was launched shortly after the *Unlog Tower* was completed with a preliminary, noninteractive virtual display of the longhouse, the platform framed house, and the trees illustrating the *Unlog* method while the interactive features (Methods 2.2-4) were being developed and refined. Prior to the completion of the *Unlog Tower,* many tests had already been conducted for the longhouse visualization (Method 2.1). In addition to the AR components, the series of exhibition panels within the tower (Figure 2) offered the visitors a detailed explanation of the Hodinǫhsǫ́:nih longhouse, the industrialization and application of dimensional lumber, and the methods for constructing the *Unlog Tower.* The exhibition was on view until the *Unlog Tower* was disassembled, a total time of 6 months.

The employment of AR provided users with a unique and personalized experience to view and understand these three distinct methods of timber construction. For the Hodinǫhsǫ́:nih longhouse, using realistic materials with transparent elm bark allowed users to visualize the virtual longhouse at scale in a seemingly natural environment; AR allowed the virtual longhouse to blend (overlay) with other real/natural objects such as trees and grasses, and nearby buildings to provide a sense of scale. Notating the detail in AR allowed users to identify where different tree species might be used for constructing a traditional longhouse. Ultimately, it was imperative to use a detail notation with a transparent bounding box so that users could easily tap on the detail through their mobile devices. By tapping on the detail, users could visualize a refined virtual articulation of the detail with the various tree species involved separate from the virtual longhouse with natural materials (Figure 11).

Figure 11. Perspective of the Longhouse through AR

The virtual aspects of the *UnFrame* exhibition visually prompt the user to consider timber waste across these three distinct virtual timber constructions. The *UnFrame* exhibition seeks to engage users to discover more information about the tree species used in the Hodinǫhsǫ́:nih longhouse by interacting with the detailed virtual reconstruction. Future investigations will explore the integration of social media platforms into the AR application to attract more visitors to the exhibition and provide a platform for virtual discussion. This could also become a medium whereby the exhibition team can receive digital or online feedback about the AR content. The *UnFrame* exhibition extends the discourse on the design and curation of interactive, publicly accessible AR exhibitions that are not confined in the bureaucracy or infrastructure of traditional museums or exhibition halls. The *UnFrame* AR exhibition is locally accessible through one's mobile device, an increasingly ubiquitous technology. The exhibit encourages its visitors to reflect on the nature of innovation in timber construction, through both historic and contemporary dialogues and references.

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