Representing Cultural Heritage Places through AR in Museums

Learning from the usage data sampled at the exhibition of Alva Aalto's Baker House

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Introduction

When the result of surveying a cultural heritage site is exhibited in museums, researchers and curators face the challenge of organizing a large number of digital and physical artifacts and selectively composing them to convey cohesive, compelling stories to the public. This paper describes a case of such an exhibition recently held traveling to two Japanese museums about Alvar Aalto's Modernist architecture. It presents how these artifacts can be curated through an augmented reality (AR) exhibit using visitors' smartphones, and evaluates usage logs collected as the visitors on the museum floor interact with the web application.[1]

The logged data includes the camera poses and UI activation status throughout each user session, and is sufficient to reconstruct the moving view through the smartphone camera under different operational modes. For example, the visitor can switch between viewing digital models that synchronously accompany a specific drawing physically exhibited on the museum floor, suspend the AR function to freely magnify and rotate 3D models, or watch videos recorded on the site. The moving view on the smartphones can be reconstructed from a log for data visualization and analysis of the observers' behaviors. This project verifies that non-intrusively sampled feedback from an interactive multimedia tool can serve as a useful basis for evaluating the users' experience. Learning from this interaction leads to opportunities for improving curation and exhibit designs.

Cultural Heritage: Baker House

Alvar Aalto (1898-1976) is a Finnish architect considered as one of the most influential Modernist pioneers. In the spring and summer of 2021, a large traveling exhibition of works by Alvar Aalto and

[1] The web contents are delivered directly from an online database, instead of a downloaded smartphone app. Anonymous information only regarding the user interaction within this web application was made available for sampling in this project through a web statistics tool.

his wife, Aino Aalto, was organized for museums in Tokyo and Kobe, Japan.[2] Among eighteen architectural projects and numerous furniture designs introduced with 223 archival drawings, models and vintage furniture placed on the museum floors was his Baker House (Fig. 1), a student dormitory he designed on the campus of the Massachusetts Institute of Technology while he was a visiting professor to the Institute.

Fig. 1. Photogrammetrically captured model of the Baker House dormitory on MIT campus design by Alvar Aalto and constructed in 1949. (© T. Nagakura and N. Vlavianos).

AR Tool and the Exhibit in Aino and Alvar Aalto Exhibition

An AR application was developed for the Baker House exhibit through a collaboration between MIT, the Aalto Foundation in Helsinki, and Gallery A4 in Tokyo. For development, several 3D scan models, CAD models, and on-site video recordings produced by the MIT team as well as a few hundred scanned, archival drawings and photos provided by Aalto Foundation were initially uploaded onto the Design Heritage[3] website, a database-driven online collaboration platform previously developed (Nagakura, Peng, Cornejo, Villalon, and Tsai. 2017). A subset of data was selected and spatially arranged with reference to three panels placed in the exhibition space:

- Three photogrammetric models. (The building exterior, fireplace in the lobby and dormitory room.)
- Two white CAD models showing the upper floor section and the roof.
- Nineteen scanned drawings and photos selected from Aalto Foundation's archive.
- Seven on-site video recordings (17, 38, 158, 26, 99, 13, and 230 seconds long.)

The curation challenge was to find a proper way to assemble a sensible combination of physical and virtual material for the public. On the exhibition floor, two A0-sized panels including printed photos and drawings selected from the AR contents are placed on a wall. The ground floor plan drawing printed at 1:200 scale in an A1-sized panel is on the small table in front of the wall. AR functionality[4] was integrated into the physical exhibition via binary markers embedded in images on the physical panels. Upon marker recognition by a visitor's smartphone camera, the pre-arranged multimedia contents appear in positions relative to these panels.

[2] "AINO and ALVAR AALTO Shared Visions" was held in Tokyo Setagaya Museum (2021.03.20-06.20) and Kobe Prefectural Museum of Art (2021.07.10-08.29). The catalog of the Kobe exhibition is available at https://www.artm.pref.hyogo.jp/exhibition/t_2107/aarutolist.pdf (Accessed: 30 July 2021).

[3] https://designheritage.mit.edu (Accessed: 30 July 2021). The platform uses Three.js library and SQL database.

[4] The Baker House AR application uses AR Toolkit available at https://ar-js-org.github.io/AR.js-Docs/ (Accessed: 30 July 2021.) It is compatible with Chrome and Safari on iPhone and Anrdoid smartphones.

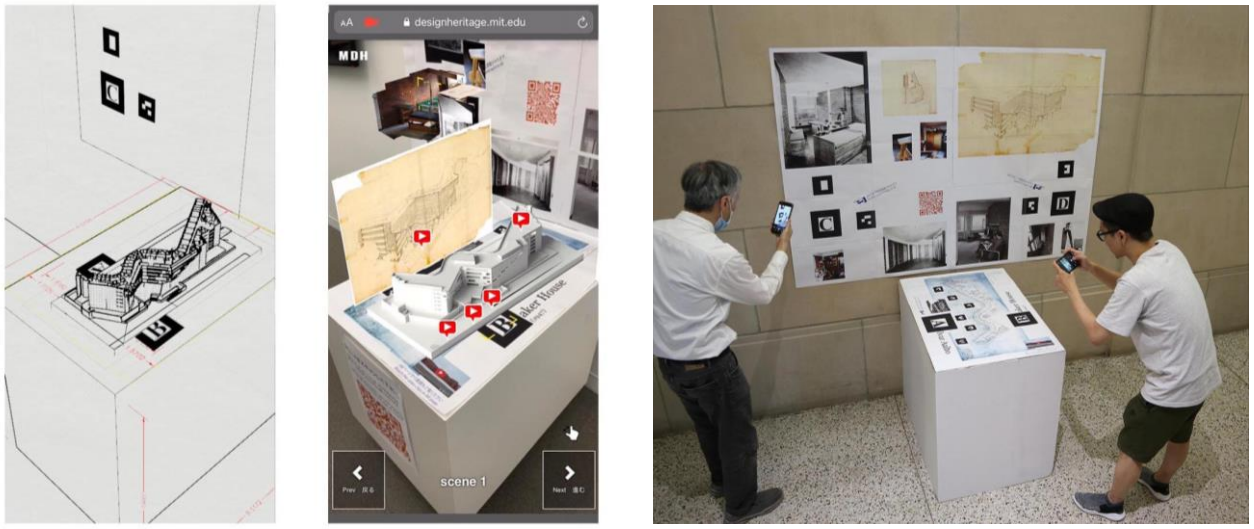

Fig. 2. Baker House AR (2021). The visitors using the application (right), the screenshot of the visitor's smartphone (middle) and the corresponding viewport state reconstructed from the camera pose and UI status logged in the usage data (left). The alphabet characters and binary patterns with the thick black frames indicate the AR markers. The red flag icons placed around the virtual model in the screenshot (middle) can be clicked to bring up on-site video recordings.

Preliminary Result and Evaluation

The potential of virtual museums over conventional ones are discussed early by Mitchell (1995, p59). The idea of Museum 4.0 has since been realized in various ways, and AR exhibits of buildings have recent precedents such as Nagakura and Sung (2017). Analysis of behavioral logs of website users have previously been discussed, for example, in Dumais et al. (2014) in HCI studies. This project examines the contents and interface particularly in the context of AR exhibitions of spatial design. The usage data of the web application initiated by the visitors on the museum floor logs the camera pose, tracks AR markers, and the activations of UI switches with a half-second interval. In AR-mode, while the visitor moves around the exhibit with the handheld smartphone, the camera's location relative to the physical markers embedded in the drawings exhibited on the floor causes synchronous updating of the view of the 3D models. By touching the smartphone screen, the visitor can switch to a non-AR "Finger-based mode", and rotate, move, or magnify the camera to freely inspect the digital models from any preferred vantage point. The data log can reconstruct the moving view through the virtual camera in both these modes, with the identification of the detected AR markers used for tracking.

This application also includes multiple "scenes", showing unique compositions of the multi-media content associated with the markers on the floor. For example, in one scene, the visitor sees the 3D scan of the building with photo-realistic texture appearing over the plan drawing on the table, while the white 3D model of a floor and the roof floating above it displays over the plan in another scene. The exhibit designers created these scenes to convey compelling stories about the building design. The visitors' changing scenes through simple UI buttons was recorded in the usage log.

Table 1 shows an example of the basic statistics taken from the logged data of 1485 visitors during the first 20 days of the exhibition. On average, a visitor used the web application for 115.5 seconds. The key findings from the statistics include:

1. Enriching contents by mixing virtual and physical exhibition media (3D models, 3D scans, videos, drawings), preparing multiple, user selectable scenes, and adding different interaction methods (AR mode and Finger-based mode) made the exhibit more engaging to the visitors as they seem to spend an additional amount of time to investigate them. Multiple scenes had a particularly pronounced impact in this exhibit.

Condition	1	2	3	4	5
Visitor category	All Visitors	Watched Video	Clicked Help Menu	Activated Finger Mode	Visited Multiple Scenes 1-3
Number of Visitors	1485	1088	75	1308	836
Total Duration (sec.)	115.6	133.5	291.9	131.2	151.3
3D Viewing only (sec.)	94.5	98.8	237.5	108.3	124.6
3D Viewing of “Scene1” only (sec.)	80.4	90.4	215.3	88.6	80.9
3D Viewing in “Finger-base Mode” only (sec.)	47.3	55.2	159.3	64.6	66.7
3D Viewing in “AR Mode” only (sec.)	47.2	43.6	77.7	43.7	55.9

Table 1. Statistics from the data logged (at half second intervals) during the first 20 days of the exhibition in Kobe Prefectural Museum from July 11 to July 31 of 2021. Logged visits of less than 5 seconds (about 5% of the total visitor counts) are included although these outliers indicate visitors just testing the application without actually using it. The comparison among the blue and red cells shows the increase of the total viewing time while the time spent on the first scene stays approximately the same. The comparison among the blue and yellow cells shows the increase of the total viewing time while the time spent on the 3D viewing stays approximately the same. The comparison among the blue and green cells shows the increase of the total viewing time while the time spent on viewing in AR mode stays approximately the same.

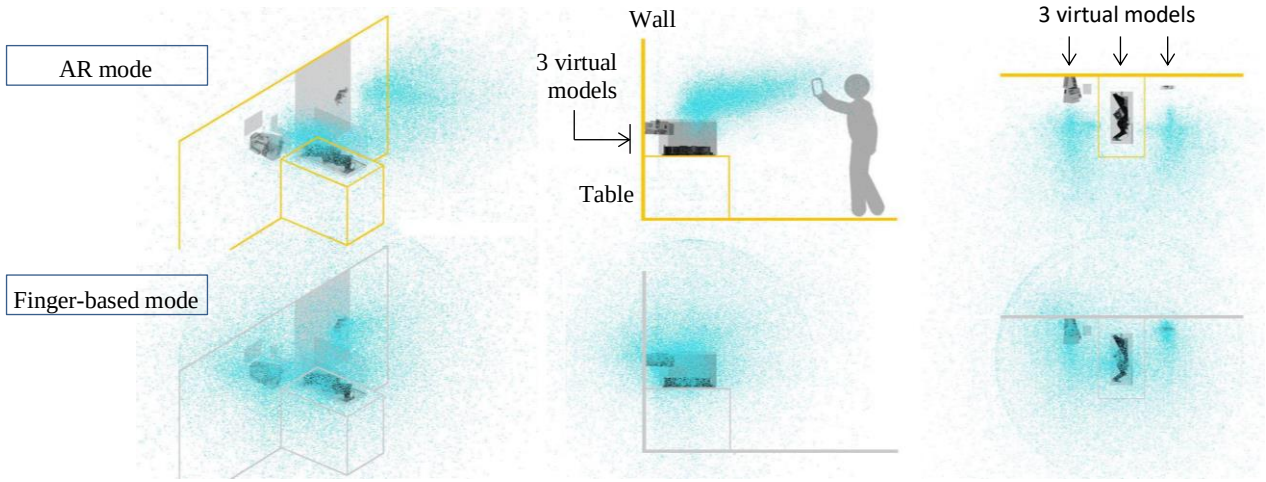

Fig. 3. The distributions of the visitors’ camera positions around the exhibit: the distribution for AR-mode (top) and the one for Finger-based mode (bottom) shown in the axon (left), section (middle) and plan views (right). Two virtual models are placed on the physical wall, while one is set on the table.

2. The “Help menu click” filtered out people who tend to invest more time in investigating the curated contents in depth. Those who took time reading the menu stayed longer with the exhibit, especially trying out the Finger-based mode which is illustrated in the help menu.

3. The way the digital model is placed in AR has a measurable impact on the spatial distribution of typical viewing angles from which the visitors observe the model (Fig 3). Not only do the walls, floor and table around the exhibit impose physical restrictions on the visitor's position, but viewers are only comfortable holding and looking through the smartphones in certain body poses. In contrast, the Finger-based mode gives users more freedom in choosing viewing angles, while curators get less control over the way the model is observed.

Conclusion and Future Prospect

This paper introduced the Baker House exhibit as a multimedia presentation of a cultural heritage building, and examined the usage log collected from visitors' smartphones. The exhibit implemented a close coupling of coordinated physical and virtual contents through its web application deploying AR, and allowed the visitors convenient access, through their smartphones, to multimedia contents such as 3D models, a large quantity of archival photos and drawings as well as video recordings. This access breaks and expands the boundary of the limited number of drawings and photos physically exhibited on the walls and tables of the traditional exhibition space. For the exhibition producers, the application provided a means to curate a story of the cultural heritage, by spatially arranging the large quantity of digital contents through AR that establishes a reference to the physical artifacts on the floor, by allowing free manipulation of the digital objects through a Finger-based UI, and by the application UI dynamically rearranging scenes.

A significant advantage of this method is its ability to reconstruct visitors' experiences from the usage log collected during their interactions with the application on the exhibition floor. Upon the examination of the usage log of the Baker House AR exhibit, the curation team was able to evaluate and verify the exhibit design and its user engagement in terms of the usefulness of the scenes rearranging the multimedia contents, AR and Finger-based operational modes, on-site video recordings associated with the 3D models, and the accompanied help menu for visitors using the application with no assistance on the museum floor.

In this paper, the usage metrics were extracted, visualized, and interpreted by the curation team in the form of simple tables and heat maps. A future prospect of this research includes the use of Machine Learning, which potentially can identify less obvious relationships between the exhibit design and the visitor engagement, and provide more fine-grained analysis, such as the angles preferred by visitors to observe a certain 3D model of a building, and popular sequences of model parts, photos and videos visitors pay attention to. Such information will be of significant value for reconfiguring exhibitions and enhancing the user experience of cultural heritage exhibitions.

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