AR-based Study of Brick Details in Heritage Warehouse

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Abstract. Industrial buildings contribute to the spatio-temporal and geographically distributed heritages. Questions were raised regarding how the heritage continued to evolve within the surrounding fabric under the unique brick details. This study aimed to explore the spatiotemporal relationship between the Former British Merchant Warehouse and its historical development of the urban fabric in Taipei, Taiwan. Historical maps and augmented reality (AR) were applied to extend the scope covered from urban fabric to warehouse brick details. The cloud-accessed 3D details were compared side-by-side under the scale referred to by the typical brick scale. The results were also reconstructed as part of the 3D documentation.

Keywords: augmented reality (AR), warehouse heritage, photogrammetry
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1 INTRODUCTION

Warehouses were closely connected to the emergence and degeneration of regional agriculture and industry. Industrial buildings such as warehouses contribute to the spatio-temporal and geographic evolvement, under the impact of technology and culture. The investment and facilities have contributed to the transportation infrastructure and hydrogeography constructions since the early period. Questions were raised regarding the roles these buildings played in the past and how the heritage continued to evolve within the surrounding fabric under the unique brick details.

This study aimed to explore the spatiotemporal relationship between the Former British Merchant Warehouse and its historical development of the urban fabric in Taipei, Taiwan, using historical maps and augmented reality (AR). The explored scope covered the scale of the regional urban fabric to warehouse brick details.

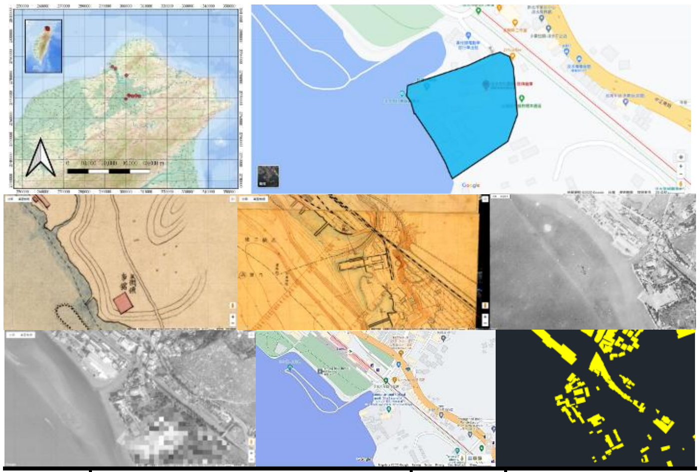
2 RELATED STUDIES

Industrial architecture heritage involves issues such as reuse [1], urban planning, urban economy [2], rehabilitation [3], and translation of incoherent place identity [4]. Since old buildings should be reused and integrated with the local culture [5], regional activation and cultural regeneration can be examined by using industrial facilities as cultural sites [6]. The spatial structure of changes in warehouse location was usually used to characterize the relocation of warehouses by land cost, tax, and infrastructure [7]. The selection of a warehouse site involves the comparison of a market's spatial characteristics. A GIS-aided process was applied to the selection decision, along with the factors of customer service and costs [8].

AR applications have been successfully implemented in a broad range of fields, including navigation, education, industry, medical practice, and landscape architecture [9-12]. The combination of GIS and AR should facilitate a detailed inspection of heritage warehouses from a macro-to-micro perspective of regional development

3 MAP INSPECTION AND FABRIC ASSESSMENT

The interactions between warehouses and fabric comprised single, meta, and determining indicators. The evolving trend of urban fabric was defined by the quantitative assessment of the architecture, river, tributaries, and railroad, based on maps created since 1895. The assessments referred to the map resources provided by the RCHSS Sinica webpages of the Historical Maps of Taiwan [13] over the last hundred years (Fig. 1). Maps were selected to present the chronological evolvement of the fabric by intervals in five to ten years or longer (Fig. 2). The range of the study started from the Quin Dynasty, the Japanese occupation period, to the present day in Taipei and its surrounding areas. As the economic and political center of Taiwan, the fabric covers the traditional municipal area, the Taipei metro area, and the drainage basin of the Danshui River.



years	map	years	map
1895	river front and tributary	1978	aerial image
1913	old streets	2022	Google® map
1921	aerial image	2023	Building fabric

Figure 1: Former British Merchant Warehouse site (top), the fabric evolved between 1895 and 1921 (middle) and 1978 and 2024 in QGIS® (bottom).

Both the warehouses and surrounding fabrics were closely connected. This cluster of brick warehouses has created a unique scene within the newly developed fabric. Both the construction material and pattern have distinguished the warehouse from peripherals by a clear boundary. The consistent development of the architecture's ascending trend of area was used as a reference indicator, by a relative scale to the fully developed stage of 100%. Target area and cross-referred trends varied from 10% to 100% in architecture, and 100% to 0% in hydrogeography. The warehouse, which was part of a tributary branch system, created an intersection in 1980. The ever-increasing urbanization accelerated the development and transformation of land for alternative use. The fabrics of architecture around warehouses shared ascending trends of development, subject to different levels of former reclamation and construction (Fig. 2).

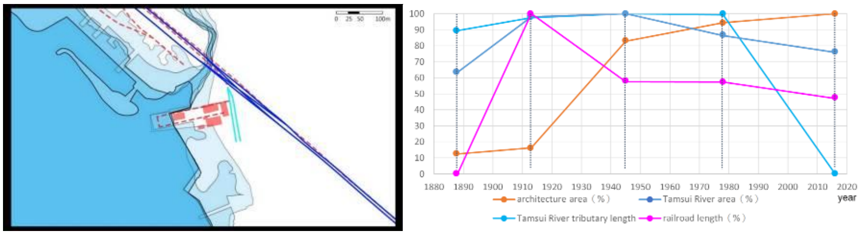


Figure 2: Target area and cross-referred trends between architecture, hydrogeography, and railroad of the warehouse

4 CONFIRMATION OF THE RELATIVE SCALE OF BUILDING COMPONENTS

The authors used images and videos as references to recreate the 3D models, which were inspected by allocating side-by-side during the interaction in visual comparison. Since the bricks were made in about the same era, the size and layer thickness were referred between two different models, and the scale of adjacent building components.

For example, the flooring was a construction system for structural support, drainage, and platform with elevation changed between indoors and outdoors. Pavement and drainage were provided in between. A typical design was the abrupt interface that existed between the building enclosure and peripheral ground earth for each building as an individual. The new building code of barrier-free design and the unified pavement design for building clusters had remodeled the interface that connects buildings, indoors and outdoors. A typical decking system was usually installed to alleviate the elevation difference and create a zoning experience.

5 CREATION AND COMPOSITION OF AR MODELS

The evolving function and fabric in the early days had created a rich building vocabulary, which should be recorded in 3D. The purpose of independent 3D reconstruction in a virtual space was fulfilled by virtual reconstruction, i.e., SfM (structure from motion) photogrammetry in the virtual space. The comparisons in historical maps are geo-referred. The 3D models (Fig. 3) were photogrammetrically created using Zephyr® [14] and converted into AR models in Augment® (Fig. 4-a), which has models cloud-accessed by scanning QR code (Fig. 4-b). The AR models were downloaded to a smartphone for situated simulations or comparisons.

Different construction styles on building corners were exemplified specifically (Fig. 3). The elegant management of molding was integrated with building components, between beam, column, wall, gable, wainscot, exterior pavement, ditches, and sewer. In contrast, the newly refurbished warehouse presented covered flooring and mostly hidden building components behind the enclosure. The representation of components and associated systematic interface contrasted more when drainpipes and wires were installed to meet today's needs. A typical glass factory was purposely created as a reference to the old vocabulary of brick warehouse. The exterior and interior components present a totally different details and setting (Fig. 4-c).

6 RECURSIVE 3D RECONSTRUCTION FROM REMOTE SITES

Smartphone AR was conducted via video conference or by person (Fig. 5-a) during the simulation process. The images (Fig. 5-b) were retrieved from the online meeting, using video conferencing (Skype®), screen share (Skype®), and broadcasting (YouTube®) as the major sources to create 3D models, inspect, and confirm 3D interacted result. Compared results were reconstructed as part of the 3D documentation (Fig. 5-c).

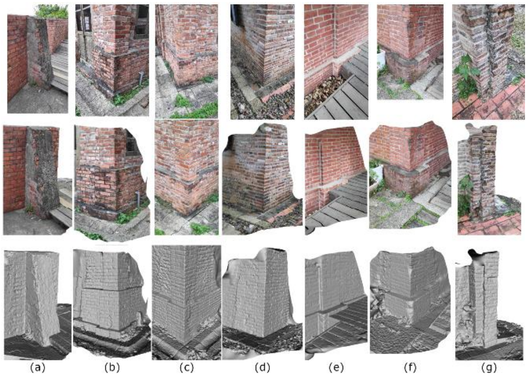
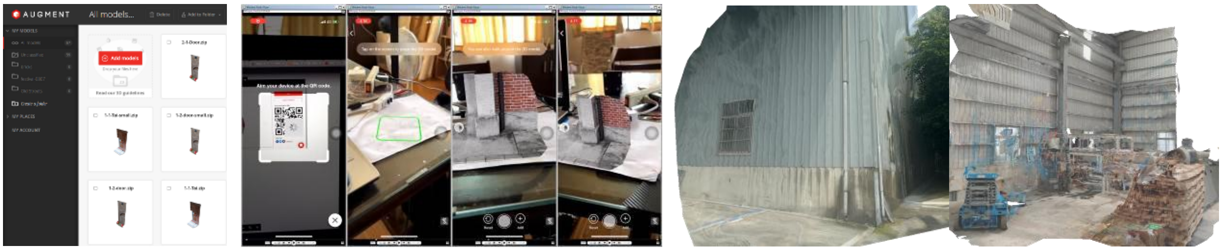


Figure 3: 3D photogrammetric modeling of warehouse corner details: (a) wall & buttress; (b) building E-1; (c) building E-2; (d) building B; (e) building D: column & wall; (f) building D; (g) building A, as displayed by field photographs (top row), 3D models (middle row), and plain models (bottom row).



(a) (b) (c)

Figure 4: (a) AR model database in Augment®; (b) QR code scan, define working plane, model adjustment in smartphone AR screenshots; (c) typical factory exterior and interior setting.

(a) (b) (c)

Figure 5: 3D reconstructed example of the 2nd reconstruction: (a) AR displayed over video conference; (b) screenshots in different angles; (c) 3D reconstruction of the side-by-side compared result.

7 COTRIBUTIONS

This study contributes to historical preservation in a constructive combination of AR inspection, video conferencing, and 2nd reconstruction of result. The advantages included the assistance made in the composition of AR models, confirmation of the relative scale of building components, communication between remote sites, and recursive 3D reconstruction.

We found the inserted AR model and the background can be reconstructed as a 3D result. This approach took a novel modeling process to reconstruct the remote interaction result again in 3D after the interaction. As indicated in Fig. 5-b, both sides of the remote parties can either take screenshots of the smartphone from different angles of the AR scene or record the conference video and retrieve frame by frame for photogrammetric modeling.

We found that a reconstructed result can be referred for a follow-up reconstruction process to verify types, evolving stages, arrangements, and the levels of remodeling made to meet today's preservation needs. Cross-referencing can be made back and forth between real and virtual models (Fig. 6-a) with assessment (Fig. 6-b), for example, of the ground-level treatment.

(a) (b)

Figure 6: The 3D photogrammetric modeling loop and assessment.

As a result, remote manipulation can generate 3D models in either virtual or 3D printed form afterward. It is proof of the result containing the relative allocation of the AR model to the background. In addition to comparing the two sets of brick details, the application can be extended to virtual installation to confirm the result. Moreover, the secondary reconstructed result can be cloud-accessed on-site to confirm former installation works.

8 CONCLUSIONS

The significantly evolved fabric had created the unique cultural identity of the Former British Merchant Warehouse. From the macro to the micro viewpoint of the urban landscape, brick construction represents a systematic process and related application of material, which contributes to the interface or connection made to adjacent parts. The complexity of a system enlightened a new approach that applied an interactive AR manipulation of inspected parts with photo-realistic texture.

Advantages can be found using the AR-enabled interface, including the advantages of the assistance made in the composition of AR models, confirmation of the relative scale of building components, communication between remote sites, and recursive 3D reconstruction. The result showed that the manipulation of building materials was closely related to the comprehension of traditional industry construction. With a close geographic relation to rivers, the distribution of architectural brick heritage depicted the historical context of a specific evolvement of urban fabrics.

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