Title:
AR-based Study of Brick Details in Heritage Warehouse

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Introduction:
Industrial buildings such as warehouses contribute to the spatio-temporal and geographic distribution, under the impact of technology and culture. Warehouses were closely connected to the emergence and degeneration of regional agriculture and industry. 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 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 from the scale of regional urban fabric to warehouse brick details.

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]. Old buildings should be reused and integrated with the local culture [5]. The regional activation and cultural regeneration can be examined by using industrial facilities as cultural sites [6].

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 [7]. The spatial structure of changes in warehouse location was usually used to characterize the relocation of warehouses by land cost, tax, and infrastructure [8]. AR applications have been successfully implemented in a broad range of fields, including navigation, education, industry, medical practice, and landscape architecture [9,10]. The combination of GIS and AR should facilitate a detailed inspection of heritage warehouses from a macro-to-micro perspective of regional development.

Materials and Methods:
The evolvement of the urban fabric was defined by the quantitative trend assessment of the architecture, river, tributaries, and railroad based on maps created in 1895. The interactions between warehouses and fabric comprised single, meta, and determining indicators. The assessments referred to the map resources provided by the RCHSS Sinica webpages of the Historical Maps of Taiwan [11] 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.

3D reconstruction was applied to brick details based on the test made on online meeting, using video conferencing (Skype®), screen share (Skype®), and broadcasting (YouTube®) as the major sources to create 3D models as a way to inspect and confirm 3D interacted result. The authors used images and videos as references to create the 3D model. The models were inspected by allocating side-by-side for the main purpose of a visual comparison. Since the bricks were made in about the same era, the size and layer thickness were referred cross models and further the scale of building components.
The 3D models were photogrammetrically created using Zephyr® [12] and converted into AR models in Augment®, which has models cloud-accessed by scanning QR code. The AR models were downloaded to a smartphone for situated simulations or comparisons.

Fig. 1: Former British Merchant Warehouse, current fabric, and old fabric.

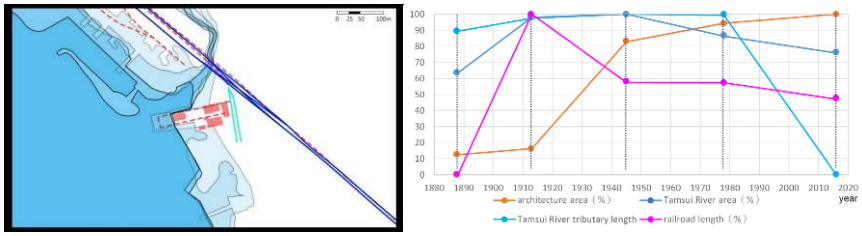


Fig. 2: Target area and cross-referred trends between architecture, hydrogeography, and railroad of the warehouse.

Results:
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 the 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 and railroad. The warehouse, which was part of a tributary branch system, created an intersection between 1895 and 2010. 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).

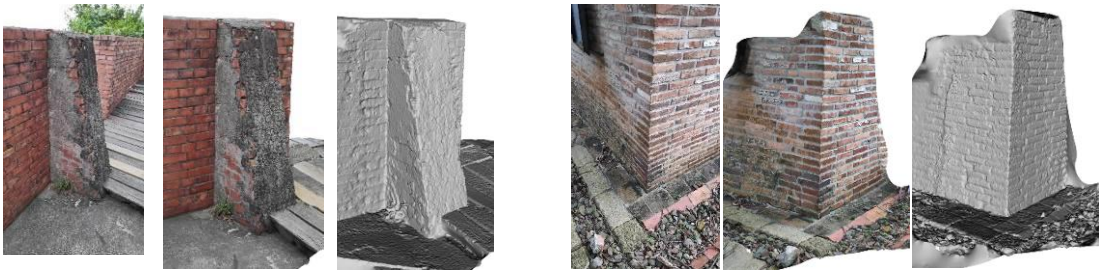
The evolving function and fabric in early days had created rich building vocabulary, which should be recorded in 3D. The purpose of independent 3D reconstruction in a virtual space was fulfilled by virtual reconstruction, i.e., SfM (structure from motion) photogrammetry in the virtual space. Both the comparisons in historical maps and AR models are geo-referred.

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

Different construction system on building corner was exemplified specifically (Fig. 3 & 4). 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 exposed buttresses and mostly hidden building components behind the enclosure. The representation of components and associated systematic interface contrasted more when drainpipe and security monitoring devices were installed to meet today's needs.

Smartphone AR in video conference was conducted during the simulation process (Fig. 5). 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 the building cluster had remodeled the interface that connects buildings, indoors and outdoors. A typical decking system was usually installed to alleviate the difference in elevation and create a zoning experience.



(a) (b)

Fig. 3: Image and 3D photogrammetric models of warehouse corner details: (a) wall & buttress; (b) building B.

Fig. 4: Examples of reconstructed components and arches of different spatiotemporal backgrounds presenting different curvatures, endings, and numbers of bricklayers.

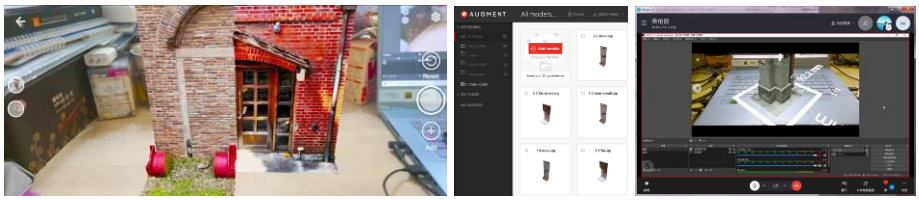


Fig. 5: Smartphone AR simulation (left), AR model database (middle), and screenshots of video conference during simulation process (right).

Conclusions:

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 enables

a new approach that applies an interactive manipulation of inspected parts with a photo-realistic appearance.

Advantages can be added to the AR process by interaction, composition, confirmation, communication, and recursion. The Advantages included the assistance made by 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 evolution of construction materials was closely related to the development of the industry. With a close geographic relation to rivers, the distribution of architectural heritage depicted the historical context of the evolvement of urban fabrics.

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