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Computer-Aided Design AND APPLICATIONS

An As-built Representation of An Urban Environment around a University Campus

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ABSTRACT

This study integrates the human issues with the corresponding technical representation of an urban block around a university campus. Regional urban fabric is represented using the as-built data for the most updated open space distribution at various altitudes, the changes made to old maps originated since the Japanese Colony age, and the street openness based on the vertical section. In order to verify the patterns of human-space interaction, 3D scans are used to provide as-built data for quantitative illustration by 3D models and for the analytic sections by means of the openness ratio. The as-built representation of the urban model shows its great potential for cross-discipline reference, as well as its feasibility for the auxiliary infrastructure of virtual urban information, not only for existing designs, but also for new regional planning.

Keywords: 3D scan, as-built 3D models, urban infrastructure, topographical data.

1. INTRODUCTION

The Chi-Da commercial district is located next to Taiwan Normal University campus, Taipei, and named after it. The space around the campus is usually full of student-related commercial activities. Due to the large number of students with limited budgets, there is a great demand for food booths or grocery vendors; this commercial space is smaller and more casual than that of a more established shopping area. The originally student-oriented shops have gradually changed the characteristics of the surrounding community by creating a space with a special atmosphere for both residents and tourists. The gradual merging process didn't become critical until conflicts occurred when the living quality dramatically plunged. There has been little documentation on the physical changes the area has undergone. Therefore, the aim of this study was to document the cultural changes in terms of the community's physical form, which have corresponded with the shifts in the living environment of the local residents.

As the original student-related activities were augmented by the current accumulation of shops, this district was transformed into a high-density and versatile community. Its development has been accelerated recently, since urban renewal and MRT stations have attracted even greater numbers of people. The interlacing of residential and commercial activity has blurred the boundaries of the original context, which was that of a quiet community. A typical feature now is the mixture of store fronts and apartment entrances on the first floor. The stores also occupy the street-side space for service, parking and utilities. Some apartments share the circulation staircase with customers. These interlaced activities are intolerable to residents because of the noise, bad smells and the impact on their privacy.

The district is also famous for being a night market. In the early days, most shops sold groceries during the day and were neither considered to be nor run as a night market. Now, the grocery stores have been replaced by coffee shops, cafeterias, south-east Asian restaurants, etc. These new shop types have created a desirable sightseeing spot which is reported on extensively on television travel channels and food channels. As well as the TV marketing, the government's travel bureau campaign promotes this community as one of the must-see locations in Taipei. Government promotions include alley culture events, beef noodle festivals, good business awards and beauty pageants. As more and more alleys have been taken over by these commercial and tourist activities, the changes in the

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environment have shifted the cultural nature of this once quiet community and, consequently, alienated the area's non-commercial-related residents.

2. 3D SCANS IN AN URBAN ENVIRONMENT

This campus block features specific urban characteristics. The representation of cultural matters requires the collecting of related urban data for the study of the relationship between scale and activity. In order to integrate data from multiple state-based sources, the barriers which exist from the technical, policy and institutional points of view must be determined [3]. The data from all platforms need to be exchangeable for the best efficiency [1,6]. The concept of cross-sourcing virtual cities [9] should be promoted to include as-built city data, so as to reflect the real content of an environment. 2D registration processes should be extended to cover 3D property registration [7], as with the integration of cultural characteristics and as-built 3D city models.

Virtual 3D city models are becoming more widely implemented by governments and city planning services; this requires highly detailed 3D models that reflect the complexity of city objects and their interrelations [4]. Nowadays, city modeling has reached a new paradigm in which 3D point cloud models have been treated with rich geometric properties and rich details, which enable the clouds to be integrated with other city model types [8]. Since the cloud models are as-built data, the integration with old environmental data leads to a specific application in showing the most current status of the environment or in contrasting the changes.

The urban 3D scan has been around for years. The LiDAR or UAV approach is able to cover the top and limited side views of a façade. The mobile approach can retrieve 3D data quickly; however, both approaches possess a large tolerance. The tolerance becomes increasingly important, since in some urban districts the real estate prices are so high that the tolerance of the boundary can cause a significant difference. This concern has modified the scan process to include a combination of altitudes from ground level and roof level. The roof level scan creates a barrier-free reference frame work with a longer scan distance, and the ground level fills in the details of the facades. The two combinations can be made from the same or different scanner types by various ranges.

The result is a 3D full-scale model created by a 3D long-range laser scanner, Leica HDS 3000®, which can reach an accuracy of 4 mm/50 m. The mode is made of an as-built environmental configuration that is feasible for creating and comparing the sections of various alleys to illustrate the transition and co-existence between residential units (i.e., apartments) and commercial spaces (i.e., restaurants, grocery stores or sidewalk booths). The invasion of public activities into private apartments can be clearly seen in the 3D model as the co-presence of first floor shops and private entrances, advertisement panels and apartment window frames, or shop fronts and temporary booths.

The creation of new scans has also been based on existing point models for a broader registration reference (up to 180 m, as compared to the common scan range of 200 m) and a better result. The new scans facilitate the integration and extension of existing urban as-built databases. Since former efforts have been taken into account, the reference framework in a larger scale has been extended and made feasible for future work. This project area measured about one square km (Fig. 1.).

Fig. 1: 3D point cloud model of the district (top) and elevation (bottom).

3. URBAN ISSUES FOR SCAN

The issues behind 3D urban scans are numerous. The data not only help in the visualization of urban spaces in different levels of abstraction, but also enable the manipulation of dimensions on different scales. The visualization facilitates qualitative study with precise descriptions of the internal relationships of artifacts, as follows:

- Archiving and re-interpretation of the "alley commercial activity" within the cultural-educational district: The "alley commercial activity" is named after its distinguishing characteristic of occurring along alleys, in contrast to shops that open onto a street wider than 4 m. This kind of activity can occur in different locations; however, the intensity can dramatically increase, especially around a campus.
- Interface between campus and commercial district: Both the campus and the nearby commercial district have different building layouts and configurations. This commercial region next to the campus was initially classified as residential blocks, with only a few commercial blocks located on the perimeter. The boundary between the two areas is physically represented by concrete walls or linear-layout private buildings. The interface between the campus and district became complicated due to the increased commercial activity. The character shift has increased traffic flow, attracted tourists (foreigners and locals) and caused more pollution. Very limited buffers or green belts are present.
- Identification of the existing conflicts between residential and commercial space: Conflicts exist in both the commercial and residential communities and in the interface area between them. The residential part of the region gradually went from being a quiet space with only local residents to a noisy and customer-packed restaurant region, in which neither the facilities nor the circulation system met the service capacity. Due to recent real estate development, the residential area now has building types remodeled from 5-story mid-class level apartments to multi-story luxury ones. The new apartments are usually allocated within a block distinguished by its height, arising from a group of lower and older buildings.

  The mixture of the two types has created the distinctive characteristics which attract visitors and increase real estate prices on the one hand, and offend the original apartment dwellers and degrade their quality of life on the other. Ironically, the people who own the 1st floor street-facing restaurants are also legitimate residents of this region who have a vested interest in the real estate market.
- Archiving the changes along the streets: The changes in the residential area, visible in the new commercial activities, from advertisement panels to commercial stands, have significantly changed the alley-side appearance and super-imposed related artifacts onto the old apartments. The street facades have been modified considerably since the early days, and it is necessary to record the most current construction status for future reference.

4. URBAN FABRICS

This region was found full of interesting living characteristics. However, based on ordinary 3D mass model, very few connections can be found between the simplified configuration and the local activity. Regional urban fabric is represented using the 3D as-built scanned for 1) the most updated horizontal open space distribution at various altitudes (Fig. 2), 2) the changes made to old maps originated since the Japanese Colony age (Fig. 3), and 3) the street openness based on the vertical section.

Fig. 3 illustrates specific changes of new constructions gradually appeared to the campus and the neighborhood. The constructions are considered as an indicator of increased student population and consequently the commercial activity under developed. The fabrics presented, as a summation of the configuration and based on the scanned data, can illustrate the cross-relationship in macro and micro forms [5], in terms of the section of an entire block and small alleys (Fig. 4.):

- Cross-section of entire block: The section is about 1 km long (Fig. 1, bottom). The skyline near the block perimeter is different than that at the center because of the different building types, development stages and zoning. The skyline changes from a great height at the boundary to lower at the inner community region, with only a few apartment buildings above 10 stories. There are new luxury apartments available for sale, while others are for rent only. The former are there to make the most of high real estate prices, while the latter are built by investors for students with limited budgets. Both building types present a new development in the living environment, as the newer wealthier residents are different from the locals, while the presence of the students is only temporary.
- Alley sections: Sections along the most popular street by intervals are super-imposed together to enhance the vertical profile of building components and artifacts (panels, window installations, facility additions). The overlapping artifacts of different proportions are presented in a specific hierarchy. Most of the facility additions do not belong to the original apartment

Fig. 2: Fabrics in 1988 (top left) and in 2014 as above 2F, 6F, and 10F.

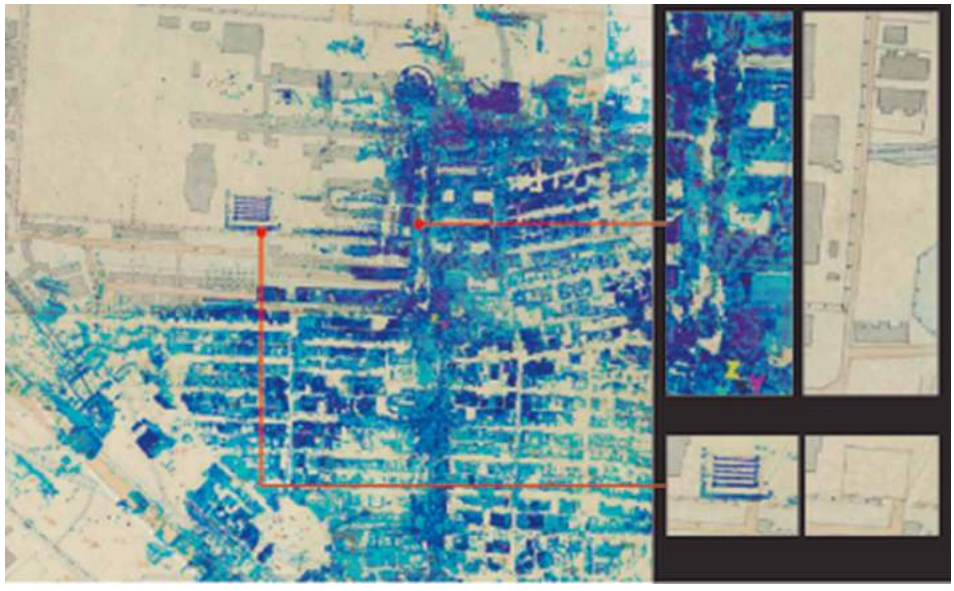

Fig. 3: Comparing the difference between old map [2] and current scans.

design and have been installed without order. Crowded with temporary pipes and wires, an alley is a self-contained world of adventure for food, clothes and ornaments, not only for college students, but for everyone.

5. OPENNESS RATIO AND SCALES

The diversified commercial activities are the result of the scale of the available spaces. Based on the scans of the as-built environment, the various spaces can be

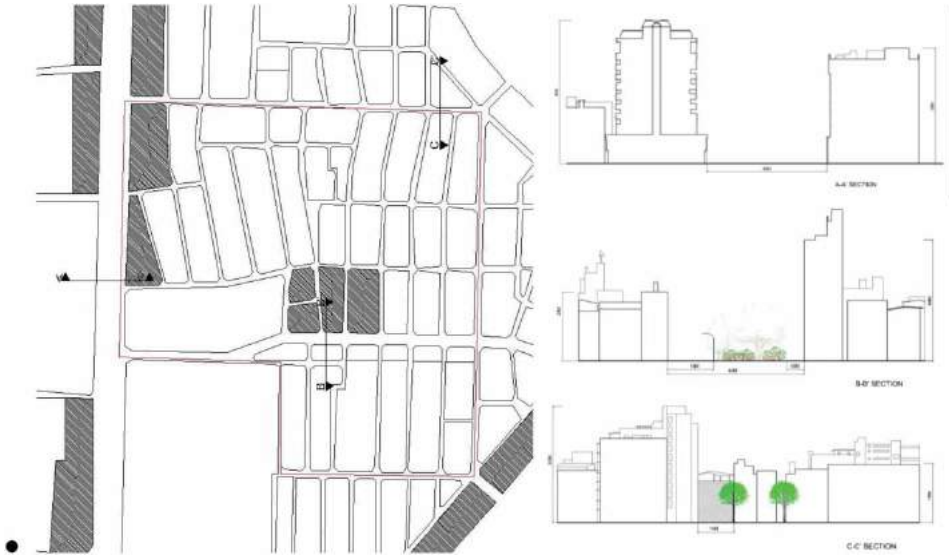

Fig. 4: Three types of sections with different openness ratios.

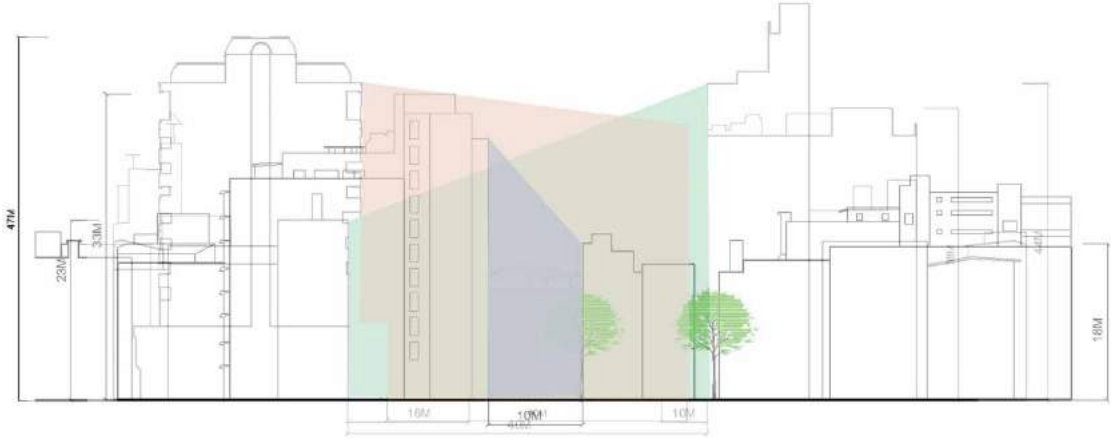

Fig. 5: Overlapped sections of the three categories.

quantified by the openness ratio in which the average height of a street-facing building is divided by the street width, as follows:

- Main streets: The entire block is surrounded by streets about 40 meters wide. A small ratio indicates that a larger open space exists; the street-facing shop front is usually accompanied by a recessed walkway, sidewalk and landscape, which provide a buffer between the heavy traffic of the street and the shopping area.
- Connecting streets: The streets inside the block connect main streets and small alleys. A small sidewalk is accompanied by some minimal landscaping. When a small park is located next to the street, the ratio varies dramatically by section.
- Alleys: The small alleys between the connecting streets come with minimum open space, and have the lowest ratio.

In order to compare the differences, the sections of the three categories were overlapped with the central line aligned (Fig. 5.) to show the configuration difference. In contrast to the common perception of the positive connection between the number of visitors and the size of the open space, the correspondence of the proportions was actually reversed. The change in ratio came from neither the proportional scaling of the open space, which varied from 1.1:1 to 2.1:1, nor the number of visitors. The ratio, in fact, led to a finding different from the general perception that the wider the street, the greater the store variety. Unlike a well-established facility on a wider street, the narrow alleys are usually over-crowded and lack supporting space. Ironically, the alley spaces become full of human-centered activity, with each one having different characteristics which encourage exploration one at a time. The quantification leads to a deeper study of the related qualitative issues behind the value of

the ratio by discovering how important the human scale and the shopping atmosphere are to the actual accumulation of people.

The ratio usually reflects the scale and the possible commercial activity types currently existing in a region. However, the real ratio reversely indicated the possible scale of related activity, in terms of the restaurant seat numbers, the width and depth of store footage and, particularly, the layout of temporary booths.

6. HUMAN-SPACE INTERACTION PATTERNS

The scans led to the discovery of specific patterns or features which exemplify the human-space interactions, as follows:

- Deployment of advertisement panels on street-facing façades: A new skyline was created by the layers of advertisement panels, original façades, modified façades and new facilities. The panels are displayed by layer of depth, starting from those closest to the street to those on the store façades. Although most of the store fronts are located on the ground floor, the panels, which are installed perpendicular to the façade, are of different heights, sizes, materials, designs and colors. The variations are shown through three types of orientation: horizontal, vertical and vertically extruded. The overlaying of multiple XY-planes is interesting, since the changing profile of the silhouette is almost aligned with the line-of-sight of pedestrians.
- Installation of illegal roof covers on low-rise apartments: The illegal or contemporary roof covers, which are shown in different colors, are usually made of galvanized sheet metal (Fig. 6, left). The slope and the space between the original roof and the sky have become typical visual characteristics. New buildings usually have a consistent roof configuration.
- Adaptation of old apartment fronts: Commercial activity has gradually invaded the ground and first floors of the old apartments, which were traditionally used for residential purposes from the ground floor up. The invasion has broken the boundary between the public and private domains, and preventing interruptions by customers is virtually impossible. The intrusion and the interruptions have caused dramatic responses from the residents against the stores. One typical example is a restaurant located on the second floor of an apartment block, where not only the noise disturbs residents, but also the kitchen exhaust lowers the air quality of the neighborhood. Banners reading “Stores get out of the community” (Fig. 6, right) are seen everywhere in an attempt to raise public awareness. Ironically, few of the stores or restaurants are run by the owners, as a majority of them are owned by real estate investors who live elsewhere. The tension due to the pollution of their living environment is actually created by the residents and the owners tied to the same region.
- Reuse of parking lot for more booths: Due to the limited supply of spaces and the large demand by individual freelancers, the parking lot has been partitioned into smaller lots for rent. Small tents, as booths, are used as temporary shelters for customers and for storage. Compared to that of parking fees, the profits from the lot rentals increased 5 times to about 30000 NT per month (1 NT is about 30 USD, depending on the exchange rate). This type of commercial activity has altered the original usage of a public facility.
- Conflicts between public circulation and commercial activities: The commercial-related

Fig. 6: Roof covers in different colors (left) and pink protest banners (right).

facility layout which has taken over formerly open space is an inappropriate invasion of the public domain. A typical example is the usage conflict over sidewalks and streets. Individual booths are usually placed on both sides of small alleys. The narrow alley width creates a perfect space for promoting an interesting browsing experience of the goods available. The number of booths can double on weekends when the sidewalks or even parts of streets are occupied.

- Missing interstitial space between street and apartment fronts: Normally, a few meters of setback would exist in front of apartments or shops. These spaces were usually used for landscape or parking; now they are furnished with seats. The interstitial space has become commercialized.

7. DOMAIN-SPECIFIC ANNOTATION: GEOMETRY AND IMAGES

Space-time recordings of residential characteristics usually emphasize the dominant behavior-related features, from the size of a building to small subjects, such as graffiti, posters, banners or signs. Some of the features are the representation of how the residents feel about the community and what their opinions are. The concerns of the public are usually evident in certain forms of visualization. One typical example is the red banner showing the dislike of the invasion by shops into a residential area. Three-story high banners were hung outside the staircase from the 6^{th} floor to the 2^{nd} floor (Fig. 6. right). As shown in the image, the banners are explicit because the entire building is being used as a super-sized bulletin board to pledge their determination to public.

Some of the signs are domestic and some are foreign. The banners represent a kind of domain-specific annotation which shows how the residents mark their boundary using any resource available. Ironically, in this case, the "resource" is over-priced real estate about 20 years old. In order to define the specific "annotation" layout, the surrounding environment needed to be recorded too. A 3D scanner with 360×270 degrees of scan view served as an efficient tool to define the subject at this specific time period of conflict. The resulting 3D point cloud model clearly indicated the subject's relation to the nearby community, or to the entire street block. The as-built model also clearly illustrated the change in the modified building from a typical apartment to a commercial-dominated renovation. The interstitial phase could be characterized and identified in the model, in which the banners, utilities and store fronts were all full-scale. In terms of the recording of the life-cycle of this community, this project was fortunately conducted during this particular space-time frame.

8. DEFINITION FOR THE CONFIGURATION OF A BOOTH'S PHYSICAL SETUP

Traversing the alleys and looking for interesting goods is a tourist's greatest adventure. An alley is usually full of different types of booths with fixed or temporary fixtures (Fig. 7.). The arrival of temporary booths happens for several reasons. One of the commercial advantages is the extremely compact installation setup which can be delivered and deployed in a very short period of time, even without a power supply. The owners usually arrive with a large but shallow case that opens up into a table top and a vertical display. In order to display as many goods as possible, walls and panels are applied in a manner whereby the entire booth can be set up and taken down at a moment's notice. The case is supported by a steel frame which is usually integrated with the case body. Both the case and frame can be carried around with ease. To prevent a direct impact with traffic or police raids, it is crucial that everything can be rapidly carried away.

Most of the booths are located along the street, with a footage about 1-2 square meters wide; the lots are allocated randomly or occupied on the first-come-first-serve basis. As a result, if there is a "clean" wall

Fig. 7: Street-facing booths of different categories in point cloud.

Fig. 8: 3D photogrammetry model of a shop front without image mapped.

Fig. 9: A merged 3D model of pts file (3D scanner) and obj file (photogrammetry) in Rhino® to differentiate the foreground (colored polygon model) from the background (points in black color).

showing on the scan model, there would be an array of booths in the evening.

The booths and shop fronts were recorded using a photogrammetry application, Autodesk 123D® Catch. The former 3D scan was suitable for a static environment, but for a dynamic scene of a booth with customers moving around it, a real-time 3D capture was required. Although, photogrammetry technology is also better for static subjects, this study used a digital camera to capture the scene and create the 3D model (Fig. 8.). The result was a realistic 3D model of peoples' activities, showing the configuration of a booth's or a shop's physical setup and the customer interactions.

9. SYSTEMS

For point cloud capture, Leica HDS 3000® is a time-of-flight laser scan system capable of afterward digital camera image mapping. It works with Cyclone® software for scan operation, cloud registration, and preference setting. Although the HDS 3000® can capture data of shop front or booth at ground floor, a photogrammetry application, Autodesk 123D Catch®, was used to create 3D model. To combine both data types, a merging platform, Geo Magic Studio, was applied for pts and obj formats. The result is an attempt to show the circumstances and the artistic conception at this region (Fig. 9). Although Rhino® and AutoCAD Revit® also accept both formats, the color attributes may not be shown completely.

10. CONCLUSIONS

The 3D as-built data re-interpreted the alley commercial activity within the cultural-educational district, and also clearly represented the interface between the campus and the surrounding commercial neighborhood. The interface area had become so interesting that the accumulation of booths attracted vast numbers of customers, and by so doing reversed the common perception of the connection between the visitor numbers and the size of the open space. In addition to adding the definition for a booth's physical configuration and the domain-specific annotation of geometry and images, the point cloud model constitutes virtual urban information which is feasible for both quantitative and quantitative studies.

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