Title:
The Assessments of Hierarchical 3D Spatial Data Comparisons in an Urban District

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Introduction:

This study applied the methodology in reverse engineering to verify the dynamic nature of urban fabric by the progress of development to date, while at the same time creating a historical connection to old map documents. From urban scale to building façade and street lamps, the methodology was approached using different types of scan data as organized in different hierarchies: general scans of the entire site from roof level and focused scans on selected façade on street level. The data types include the point clouds retrieved in Leica's scan worlds and Faro's scans, with selected regions using Asus Xtion Pro. For the first two types, the registrations were made under Cyclone's, by importing Faro scans as separated scan worlds. The 3D scan data were also orthogonally projected to verify the correctness of 2D facility map of street lamps.

Urban fabrics, as a summation of urban artifact configuration, do not usually feature consistent appearance and structure over several years. The changes actually illustrate the flexibility of what an urban space framework can achieve, and interpret the cross-relationship between buildings and temporary fixtures in macro and micro forms [7]. Identifying the changes requires, first, the representation of urban fabrics, and the second, the collection of related data to verify the relationship between space and new modifications.

Making inspection directly from point clouds should be most effective and efficient. Merging two different sources of data are proved better for visualization [2]. Merging two different platforms of 3D scanners are now proved even better to support multiple hierarchical assessments of various comparisons. City models can be created by at least three main geometric approaches: conventional techniques, high resolution satellite images with Laser scan, and terrestrial images by photogrammetry [8], nevertheless, different levels of precision apply. The concerns are if the details are feasible for practical inspection to certain smaller scale. 3D city models using a digital map and panoramic images are straightforward [4], but more details are required for architectural practice. 3D objects from point clouds are also developed with success [5], the model details are good for conceptual study, not quite sufficient for architectural representation. For the test of detailed urban data, utility Information is important [6]. But the correctness remains to be verified, since field modifications may not be updated.

Consistency among Hierarchies:

The methodology was applied to different maps: historical maps, geographic maps, and lamp maps for consistency checks. For installations not on map, on-field scans were made to mark the difference. As a quantitative study, the displacements of real object were exemplified with the value measured after projecting 3D point cloud model on maps. As a qualitative study, the integration of scan hierarchies before the data were applied to other hierarchies was explored in order to make comparisons.

The procedure consists of 3D scans that verify urban changes in a chronological manner, using an as-built geo-reference of urban fabrics to identify inconsistencies between 3D as-built point cloud models of Taipei, Taiwan. Consistencies found among hierarchies enable the comparison made in this study, and illustrates the dynamic nature of urban development over many decades to the present day. Inconsistencies between different periods of time not only show the nature of development during different time periods, but also cover various versions of maps or drawings across different departments, from various time periods. This consistency study is part of a series of study efforts towards scanning Taipei's urban environments, which are closely related to people's daily living experiences, in order to illustrate different versions of a digital city. The scans were conducted at downtown areas and specific open spaces. The former consist of a mixture of office buildings and residential apartments, while the latter includes the Shan-Ti Boulevard, which is located among a series of department stores.

The scan-data-based urban fabric illustrates the cross-relationship in terms of map scale and building scale. In order to conduct this study, the data comparison was made in a hierarchy from the scale of an urban district, a building part, to street lamps, i.e., from a map scale to a mm scale. The former consists of the historical drawings and aerial maps of Taipei [1] created during the Japanese rule period (1895-1945), 1945, 1958, 1969, 1973 and 1980, to be compared with the 3D scans made during 2011 and 2012. The latter scans also include the most current scans exemplified in early 2013 and 2015 for a building and a street. For comparison at a micro scale, a scan was made 1) at a boulevard before and after Christmas; and 2) at a street for facility check.

The dynamic nature of urban fabric

The dynamic nature of urban fabric comes from the constant changes of environment, and as a result, causes inconsistency between maps and scans. In order to discover and to record urban fabric changes through the chronological stages, comparisons are made on an urban scale, for the assessment of temporary structures on ordinary days and during festivals. To achieve this, this study starts from developing a methodology to view the data in a multi-hierarchical spatial structure, and provides a new systematic platform in retrieving and processing related information. Along with the hierarchical level of data, the methodology is feasible to check the inconsistent phases of urban fabrics in different scale, parts, or dates.

This study extended the size of the boundary and the complexity of contents of an urban environment by using a Leica HDS 3000® and a Faro Focus 3D® laser scanner (Fig. 1 left). The former was used for map-based comparisons over and area of about 250000 sq. meters under a range of 250 m. With a range of 80-120 m, a region of about 150000 sq. meters was retrieved by Focus 3D ® for more detailed comparison. The scans in different hierarchies is represented by general scans (Leica®), focused scans (Faro®), and hand-held scans (Asus Xtion Pro®) at selected areas (Fig. 1 right). The result is a set of cloud models of about 1.5 billion points each. To view the model, other than by the scanner's host platform, the data was exported under different resolutions to 3D Reshaper®, Meshlab®, CloudCompare® and Geomagic Studio® for visualization purposes.

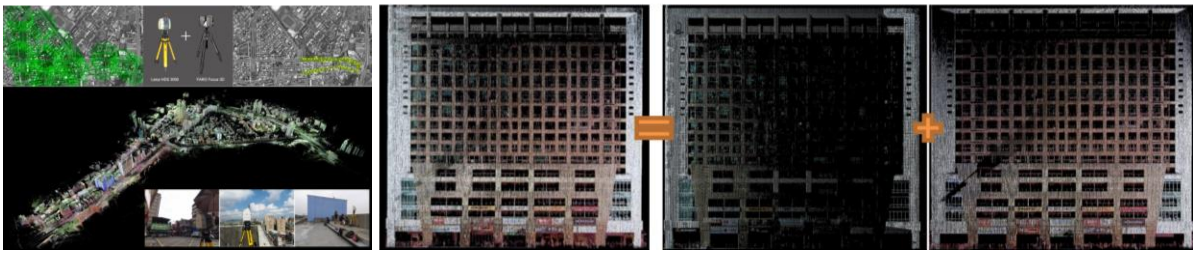

Fig. 1: The scan scope and the scans in different hierarchies (left) and focused scans (right).

Verification through Comparisons:

Urban fabric usually specifies the physical presence of existing structures. Examination of both permanent and temporary structures helps to understand the specific activity occurring within the framework. For the comparison by details, a dedicated scan region is used to prove that any part of an urban scan can be focused to identify the different settings in an occasion on a different site. The scan data enables 5 levels of comparison, from the urban scale to the block level, street level, building level

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and detailed level. The methodology of comparison starts from several procedures with the requirements, method, and procedure as follows:

- Initiation: collect data and reference to compare and to be compared with.
- Verifying scope and feasibility: must cover different scales from urban to detailed, as mentioned above.
  - Algorithmic calculation: identify a small region of interest by showing difference.
  - Overlay: visual inspection by orthogonal overlapping layers of maps to eliminate calculation burden.

Comparison by Decades

A place can remain in peoples' memories by relating place identity and self-identity [3]. 2D Maps of a certain era are usually used to symbolize a memory shared by local people and visitors. For the integration of cultural characteristics and as-built 3D city models, 2D information should be extended to be registered with 3D properties. The comparison between as-built urban environments and maps was conducted in two manners: 2D overlapping and 3D overlapping. The former combines 3D point projection images and map coordinates to reveal the possible trails of urban renewals. The comparisons were made to the maps by decade, starting with the Japanese rule period (Fig. 2) in 1980. In order to illustrate the changes made to a local area, partial images were enlarged to indicate where the major changes occurred, and how the new buildings were allocated, using different colors.

There are 5 types of changes to be identified:

1. Total demolition
2. New construction after demolition
3. Renovation: renovation as partial changes which are not easily identified.
4. Deformation: minor shape changes due to damage to existing buildings or deformation of landscape. The situation is same as above for potential difficulty in identifying the location and amount of distortion.
5. Relocation of facilities: Miscellaneous objects like electricity poles can be measured in terms of direction or distance to their previous locations.

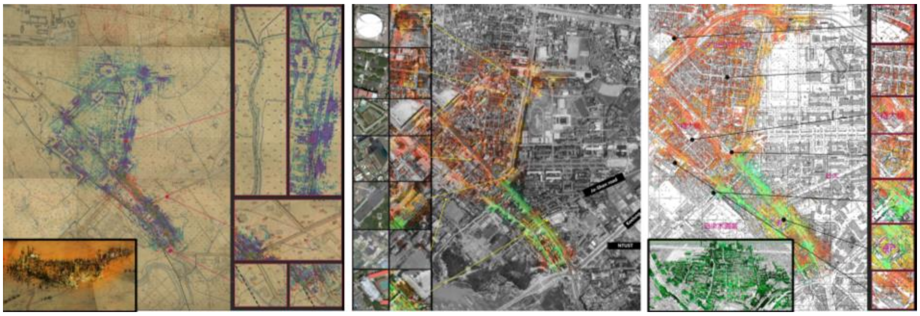

Fig. 2: The comparison between the point cloud and the original survey map drawn during the Japanese rule period (1895-1945), 1973, and 1980.

Comparison by Details with measurement

Even with accurate 3D scan data available, an urban environment is constantly evolving as a result of occasional building remodeling, which often does not necessarily keep to the originally licensed design in a permanent form. On many special occasions, temporary constructions are made only for a certain period of time, and are removed or demolished afterward. Traditionally, any remodeling requires approval from government before construction can proceed. Filing of permanent construction can be regulated by building codes with records to be referred in the future. Temporary constructions, however, which still require license applications, have become far more common recently, and as a result it has become difficult to conduct inspections if construction has been demolished afterword. In order to determine if the surroundings have returned to their original setting, a more dynamic and prompt checking procedure is required for this situation.

3D scans are feasible for conducting measurements at BIM LOD 500, with/out the festival-specific temporary settings. The scanned subject includes the open space decorated during festivals, and the space during Christmas 2014. A plaza around the main seasonal scene was selected for illustration. The scans have three versions: night scenes, daytime scenes and scenes outside the Christmas period. The difference indicates the relationship between temporary structures and the urban fabric.

The festival-settings, which don't appear during the rest of the year, were registered and computed using scan data. In order to compare two-point clouds, two sets must be well-aligned to contrast differing elements. Most of the comparison can end here, because the non-overlapped parts usually stand out from the rest, and can be visualized with properly colored clouds.

Three empirical methods were applied and illustrated. Geomagic Studio® is used as an indirect identification approach. A well-controlled registration interface facilitated the application for the registration mode of one, three, and multiple reference points. No Boolean operations of cloud sets were provided, and only visual examination was applied. Deviation analysis was illustrated in different color ranges, and was used to identify non-overlapping parts. Leica Cyclone® is similar to Geomagic Studio®; however, a "compare" option can be selected in "analysis" after two clouds are registered. CloudCompare® is the most direct approach of identification. Cloud is divided into overlapped and non-overlapped parts with the deviation analysis illustrated in different color ranges (Fig. 3 left).

Software cross platform collaboration of data manipulation was enabled in which the non-overlapped part of the cloud was imported to Geomagic Studio® for area estimation. The largest element was the Christmas tree, surrounded by many smaller objects like people or landscape elements. The area was 208 sq. meters, because there were many small differences, and the Christams tree featured a complicated configuration.

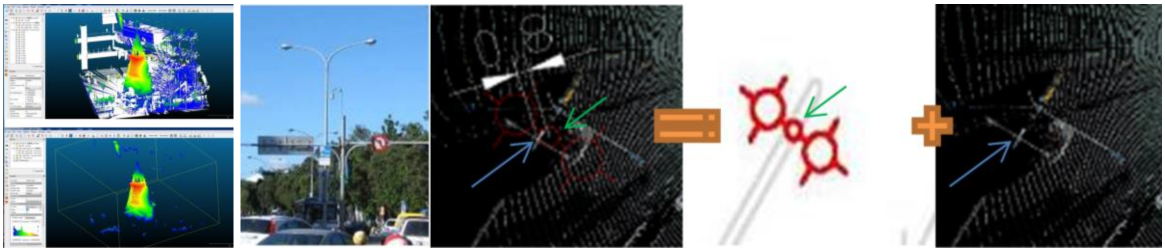

Fig. 3: The illustration of temporaru installation before and after Christmas (left) and the 0.8 m difference of displacement between the map mark and point model (right).

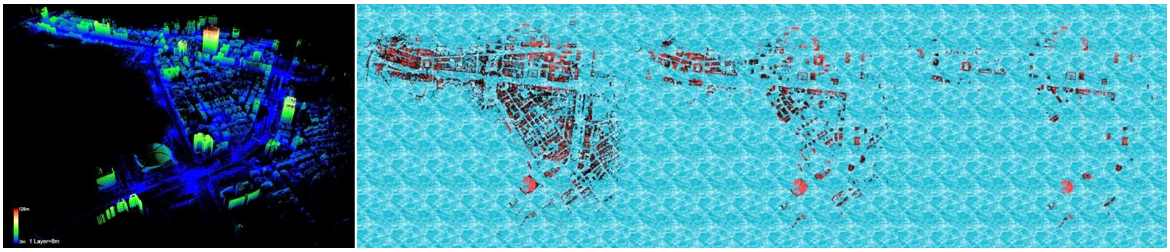

Fig. 4: A simulated flood at the altitude of 12, 25, and 35 m.

Quantitative measurements

For update status in BIM 500, the reverse engineering was applied to compare the difference between the real locations and the drawn location of street lamps on geographic maps and lamp maps (Fig. 3 right). Measurements indicated displacement did exist between 0.55 m (minimum) and 8.49 m (maximum), comparing to 1.35 m and 6.53 m on geographic map. Two marks were missing on lamp map, comparing to 26 missing marks on geographic map. When the inspection is extended to the entire street beyond the scope of this study, only 11.6% are located within 1 m of as-built corresponding location, among 640 street lamps indicated on lamp map. Among 597 street lamps on geographic map, only 3.8% are located within 1 m. The assessments of 3D spatial data comparisons in an urban district were also made in different hierarchies. For the entire model, the simulated flood altitude was visualized at the level of 12, 25, and 35 m (Fig. 4).

Conclusion:

Half of the comparisons were made between inconsistent data types, which were also represented in inconsistent hierarchies. This study has proved that the conceptual map hierarchy can be replaced by 3D spatial hierarchy that is made by scan data under different scales. Instead of system-dependent exemplification, spatial data should maintain details for the application cross different system platforms. The development of data test starts from a combination of data retrieval platform in a different scope and resolution to a single platform of a uniform resolution: from Leica HDS 3000 + Faro Focus 3D to Faro Focus 3D only, as from a larger scope of urban framework scan to the registrations with detail scans. The scan data collected in this study are so accurate that they can be shared across government departments as the most updated digital reference. Periodic scans from the same locations are always recommended for data inspections and maintenance from the life cycle point of view.

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References:

[1] Department of Urban Development; Taipei City Government: Historical maps, 2014. http://www.historygis.udd.taipei.gov.tw/Urban_e/map/

[2] Fruh, C.; Zakhor, A.: Constructing 3D City Models by Merging Aerial and Ground Views, 3D Reconstruction and Visualization, IEEE Computer Graphics and Applications, 23(6), 2003, 52-61. https://doi.org/10.1109/MCG.2003.1242382

[3] Hull, R. B.; Lamb, M.; Vigo, G.: Place identity: symbols of self in the urban fabric, Landscape and Urban Planning, 28, 1994, 109-120. http://www.issw.ch/info/mitarbeitende/hunziker/teaching/download_mat/Hull_et_al_1994.pdf

[4] Kim, H.; Kang, Y.; Han, S.: Automatic 3D City Modeling Using a Digital Map and Panoramic Images from a Mobile Mapping System, Mathematical Problems in Engineering, Vol. 2014, Article ID 383270, 2014, 10 pages. http://dx.doi.org/10.1155/2014/383270

[5] Lafarge, F.; Mallet, C.: Creating large-scale city models from 3D-point clouds: a robust approach with hybrid representation, International Journal of Computer Vision, Springer Verlag, 99 (1), 2012, 69-85. http://dx.doi.org/10.1007/s11263-012-0517-8

[6] Mali, S.; Panhalkar, S.; Pawar, C.; Das, S.: Generation of 3-D City Model for Urban Utility Information System Using Digital Photogrammetry & GIS Technology, Global Journal of Researches in Engineering General Engineering, 12(3), Version 1.0, 2012, 26-30. https://www.researchgate.net/publication/282002657_Generation_of_3-D_City_Model_for_Urban_Utility_Information_System_Using_Digital_Photogrammetry_GIS_Technology

[7] Shih, N. J.; Tzen, S. C.; Chan, T. Y.; Lee, C. Y.: Cross-Verification of As-Built Point Cloud and GIS-Related Map Data, Open Journal of Civil Engineering, 3, 2013, 219-227. http://dx.doi.org/10.4236/ojce.2013.34026

[8] Singh, S. P.; Jain, K.; Mandla. V. R.: Virtual 3D City Modeling: Techniques and Applications, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-2/W2, ISPRS 8th 3D GeoInfo Conference & WG II/2 Workshop, 27 – 29 Nov. 2013, Istanbul, Turkey. http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-2-W2/73/2013/isprsarchives-XL-2-W2-73-2013.pdf