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Paper 55

Three-Dimensional Scans of the Taipei Commercial District

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Abstract

This paper describes an on-going project with the purpose of building a digital urban landscape, of Gongguan Taipei, for academics and practitioners. Precise urban data around sites are provided and professional practices can use the data to evaluate the environmental impact of new projects. Scans were made of a street and surrounding buildings in the center of Taipei city, based on as-built environmental information. A three-dimensional long-range laser scanner was used to record buildings, plants, and open spaces in a static configuration, as well as the records of pedestrians, vehicles, objects in a dynamic form. As the scan tolerance can be controlled at less than 4 mm/50 m, the final urban information management system creates a precise description of objects with colours and textures feasible for internet browsing as well as for infrastructure dimensioning and construction monitoring.

Keywords: digital urban model, scans, information management system.

1 Introduction

The purpose of three-dimensional modeling is to provide a manner of communication among different users. This is particularly true in creating three-dimensional urban models which not only provides an intuitive way for visual communication, but also facilitates and supports the comprehension in urban development, spatial analysis, and decision-making. Due to the large amount of complicated static and dynamic information, the need for urban as-built information is obvious. The information system can be used by government departments, urban and rural area planners, environmental protection agencies, telecommunication companies, and by other expertise in consulting, architecture, and engineering. The demand types and application patterns are of concern.

Traditional three-dimensional urban models mainly come from the input and computation of two-dimensional information, which needs additional efforts to create details, to map images, and to analyze activities. Aerial photos provide 2.5D information but lack detailed description of urban as-built forms. Recent scan application in architectural survey has been enlarged to urban scale and be integrated with computer vision, digital photogrammetry, and computer graphics [4,6,9,10]. In the Finat's study [3] of small towns and midsize urban spaces, the space information and the cases were categorized based on the characteristics, purposes, and contents of subject. Computer vision software now facilitates three-dimensional modeling with registration function [5]. High resolution digital photogrammetry also provides three-dimensional environment reconstruction function with correct method to confirm results [11]. In architecture, three-dimensional scan has been used toward more complicated building configuration [1,2], and the information management and verification systems for different resolution are needed. Close-range laser scan and high resolution data retrieval is also under development [7].

Car-loaded scanner can be used in large urban area with higher efficiency [4], however, the cloud data have lower accuracy comparing to a fixed scan station and limited scope and range comparing to roof-top scan. Current software development tools interchange and rebuild data between two-dimensional range imaging and three-dimensional data [5], but the integration between general three-dimensional scan information and details still needs future development [8].

The purpose of this research is to build three-dimensional digital urban landscape (also called urbanscape), based on as-built environmental information in Gongguan, Taipei. The three-dimensional information will be used to create an information system used by academics and practices. The design studios would have more precise urban data around sites, and the professional practice can use the data to evaluate the environmental impacts of new projects. A three-dimensional long-range laser scanner is used to record buildings, plants, and open spaces in static configuration, plus the records of pedestrians, vehicles, objects in dynamic form. As the scan tolerance can be controlled in less than 4 mm, the final urban information management system is to create the precise description of objects with colors and textures. The system should also be feasible for urban infrastructure monitoring.

Previous local scans have been made to three streets about 16 km in total. The whole project aims at the urban space re-discovery, inter-relationship identification, behavior observation, historical subject retrieval, etc. Eventually the three streets along with the blocks in between will be recorded. Fig. 1 shows a street intersection at this region. Scans were made on ground levels and on roofs along both street sides. Final cloud model was registered using reference points inside overlapped areas of adjacent scans. Individual scans and the final model are three-dimensional files which can be translated into other three-dimensional formats to work between different CAD platforms or to browse in different VR systems.

Gongguan, Taipei, is located at the key intersection of public transportations like bus and Municipal Rapid Transit (MRT) systems. The region is also famous for being an "educational district" which includes an elementary school, a high school, and a university. The transportation- and culture-related characteristics make this place very popular for young consumers. Stores in different varieties (night markets, street vendors, or shops) open through mid-night. The commercial pattern and store types exemplify nowadays city scenes and a perfect scan case also. The scans include:

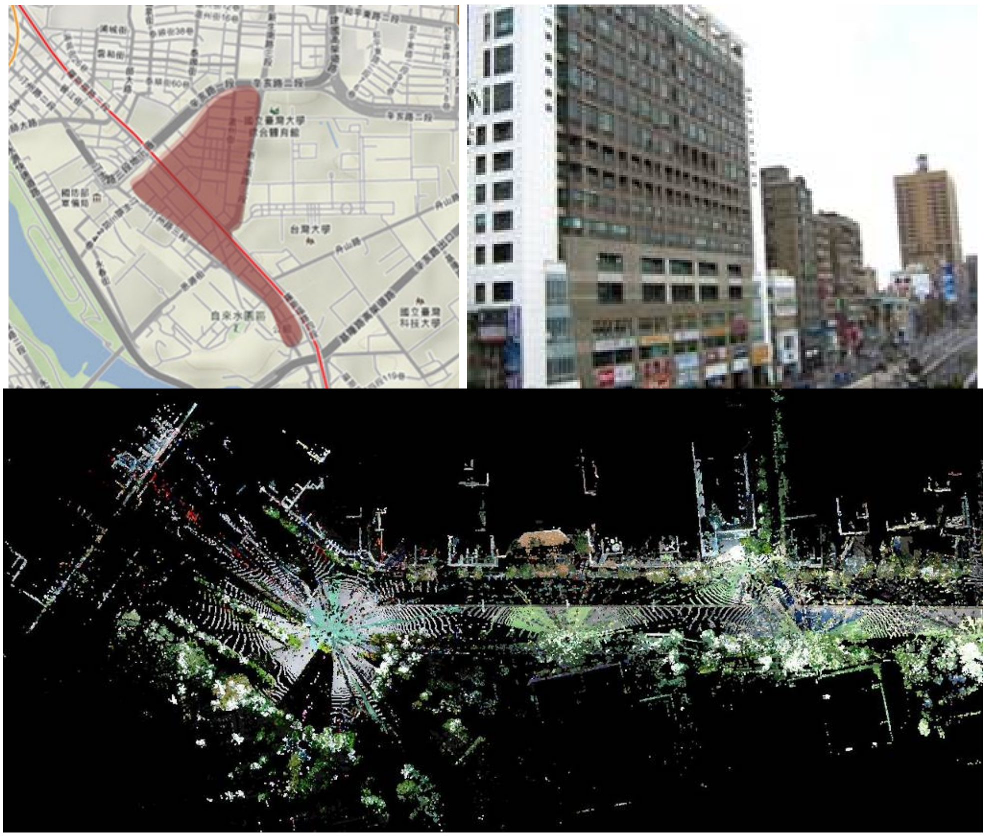

Figure 1. Regional map, scene, and street intersection in point clouds

- the facilities around MRT station;
- the installation of permanent and temporary store environments;
- the interface between streets and campuses ;
- the interface between streets and open spaces.

2 Digital Urban Models

Three-dimensional urban models are usually created by extruding aerial photos or government land records into volumetric mass. The former has accuracy up to 10 cm, and the latter uses field measures to define property boundary. Most of the sources are two-dimensional data and subject to additional field measurements or the retrieval of original design data to create three-dimensional models. For as-built description of an environment, even more on-site measurements have to be made to ensure the existing data are accurately updated. While the urban spaces are involved by different government departments, the integration of urbanscape subjects has to prevent the format fragmentation or to assist editing agents. A mechanism which defines the inter-relationship between source providers is in great demand and the final registered three-dimensional cloud model can provide a relatively complete data description to ensure the consistency between different departments.

The “digital urbanscape” is contributed by static and dynamic scenes of environments. While an environment is scanned, in the mean time the behaviors of occupants are also recorded. Traditional scan usually categorizes the interference of plants, pedestrians, vehicles as “noise” which has to be deleted afterward. In this study, instead, the “noise” becomes part of dynamic scenes to be used as an evidence of human-environment interaction for the evaluation of circulation system and opening allocation. The “noise” parts came from unexpected intrusion of pedestrians or vehicles in scans, however, turned out to be a perfect indication of human behavior of the people’s response to layout. The interaction between people and as-built environment occurred at shop front or street corner, in terms of urban furniture, landscapes, or other installations. By excluding surroundings of a focused region we can pay attention to the subject in full scale and in a much more focused manner in addition to an image-based description.

As the scan data are capable of recording exact locations of objects, the scanned routes of human beings, vehicles, cargos are used to illustrate the result of interaction with the gateways and circulation systems inside a region, an open space, or in front of a building. The records include movements, casual stops, intermediate actions, or special occasions (festivals, celebrations, parades). The static background environments are scanned before the activities occur. Comparing scans with/out activities is a way to observe a space and evaluate its post-occupancy.

The scan enables a three-dimensional-based description of context patterns which are categorized by spaces and users. The main category is classified by plants, noise, façade, and street sections. An environment can be changed due to new construction, renovation, demolition, or growth (plants), the urbanscape remains static or close to static during each scan. The scans retrieve as-built data as cloud models (made of point clouds) and polygon models.

3 The Integration of Urban Elements

Different urban regions have been planning and remodeling over years. As construction schedule cannot be recorded in a single scan, a chronological series of scans have to be made to collect sufficient amount of data for analysis. The collection, retrieval, and maintenance of urbanscape data demands long term effort and should follow a city’s development. The data should be life-cycle-aware even before the first scan begins. Since a great number of building or regional renovations are undergoing every day, the geometric data documented before can be referred afterward, for example, by overlapping scans to verify the changes. Overlapping periodical scans at the same places is an efficient way to quantify the progress or changes.

The scans of urban circulation system are very important in creating a framework to integrate previous and future works. The scan schedule is planned based on two principles: 1) to expand former scan scope from individual building to regions; and 2) to record the urban development process. Previous scan-related works sum up about ten years efforts. New scans are carefully planned to indicate the undergoing construction schedule as part of chronological records for future comparison.

The scan data are also used to combine geographic information with daily scenes. The presentation of urbanscape and the most updated construction process is made by overlapping aerial photos with three-dimensional scans. A reference is presented with facades and details available in three-dimensions up to the resolution of 4 mm / 50 meters citywide.

Interaction between designers and environments which used to be studied based on design data now can be made in as-built three-dimensional form (Fig. 2). The reality of urban scenes can reach at a higher level, typically in terms of human figures and trees (Fig. 3). The trees in a university campus are presented with more realistic details and shapes than the symbols found in common three-dimensional software. The mass, proportion, and details appear to be the most realistic even made. In contrast to two-dimensional land registration drawings, a user can browse block by block of three-dimensional scenes similar to the translation, scaling, to rotation of computer models in virtual reality. Earlier tests import point clouds to GIS platform to integrate with satellite images and aerial photos (10/20 cm resolution); however, this manipulation turned out to be sluggish or even crashed at the data level of about one million points. In order to display the urbanscape more efficiently, a new platform is designed to present the whole scene by city blocks and to visualize results through appropriate internet-friendly format (i.e. vrml).

Figure 2. Three-dimensional point cloud (left) and matching photograph (right)

Figure 3. Street scene near a campus

4 The Façades

Facades and skylines are the major identifications of a city. Skylines are not only made by roofs, but also the installations on it (Fig.4). Most of the facades are divided into three parts: the ground level with recessed enclosure for entrances and weather protection, the body with evenly divided grid pattern, and the roof with service towers, antennas, and advertising panels. The street width contributes a building code defined ratio for building height. As the average building height is about ten stories, building front becomes a perfect location to draw a driver or a passenger's attention even in a construction site.

Figure 4. Façades and skylines on one side of the street

Most of the buildings are offices and apartments. The entire façade has gaps, which are made by low rise temple, park, or other streets. The infill open spaces and the buildings create a specific solid-void rhythm which is usually considered as an identity of this area.

As tested in photogrammetry modeling, more visual details can be seen (Fig. 5). However, the precision level is decreased and building components are less identifiable than the corresponding three-dimensional scanned parts.

Figure 5. Street scene created by photogrammetry method

5 The Scan System

Instead of using traditional survey data which were retrieved discretely and manually, this study applied a long-range (350 meters) three-dimensional laser scanner, the Cyrax 3000 (Fig. 6), for continuous data retrieval. The system comes with Cyclone 5.6 software for scanner control and data manipulation. A Class B laser is used and the distance is measured by the differentiation of time the laser spot travels between the scanner and the target. The laser scanner projects laser dots in 360x270 degrees. Actual density can be different in width and height depending on the distance specified between two adjacent dots at a certain distance away from the scanner. The laser dots in a scan or registered scans form a "point cloud" in which each dot indicates the x-, y-, and z-coordinate of the point. A point cloud represents a collection of geometric data, which belongs to an object's surface and therefore can be used to show the appearance of the object. In the database, point clouds are represented in terms of scanworld or scans with exported data contain x-, y-, and z-coordinates and attributes, such as intensity, or color. A three-dimensional scan is considered to be non-intrusive technology. Therefore, areas blocked by other objects can only be scanned from other orientations. Scanned point clouds were wrapped into three-dimensional surface models for visualization and the creation of section profiles.

Scans can be made individually or registered into a large project by referring to tie-points or reference points. Each scan has a tolerance of 4mm/50m (2mm/50m in face model). The system comes with a notebook computer to handle the data received on site. Additional data operation was made on a desktop PC. PC and the notebook are upgraded periodically.

Figure 6. A three-dimensional scanner

6 Conclusion

Scan data, in terms of point clouds, were retrieved to represent the as-built geometric information. The digital models were used as the references for chronological comparisons to discover possible configuration changes or construction process. While the study scope has extended from a building, street blocks, to whole street, the mutual relationship among individual building is included to provide a more precise description of environments for design and planning control. The relationship helps to put together aerial photos and scan data. The integration is life-cycle-aware and is feasible for future construction reference. With the whole area scanned, the model not only defines a city's appearance, but also makes the data available for code checking.

Future work will be extended to other major streets to have the whole city scanned. Eventually all the city area will be scanned to establish fundamental references for academic studies and professional practices.

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