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Viewpoint

Digital preservation of a Taiwanese historical settlement: Using 3D post-construction scan to develop an application framework and reference for Beipu Township

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ABSTRACT

The purpose of this study is to build a post-construction 3D computer model of the historical settlement of Beipu Township in Taiwan as an application and reference framework. The cultural assets were digitally preserved in a post-construction and modified form as an attempt to fulfill the life-cycle management of data for culture workers, researchers and architects. The scan process was managed in four hierarchies: the whole region, the seven historical buildings, the four streets and the special features, in different scales. The final digital model integrates research results from all involved parties, integrates local practice needs, represents hypothesis in city development, enhances historical understanding and interpretation, and facilitates remote access.

Introduction

Beipu Township, which dates back to the Ching Dynasty, is a traditional Hakka settlement in northern Taiwan (Beipu Township, 2009; Beipu Township of Hsinchu County, 2005). This small town is full of family temples and old houses, and is one of the settlements with the highest density of historical buildings. The central area is surrounded by four major streets, with most of the original scenes unchanged. The building layout was designed according to Chinese Fengshui, and the buildings are typical representations of old time construction materials and technologies. Most of the residents within these historical blocks are local people, whereas the residents of the streets surrounding the area mainly originated from other regions.

The richness of the cultural assets makes Beipu popular for sightseeing (Leun, 1990), and because it is only one and half hours drive from Taipei, the streets are visited by many tourists during holidays. The promotion by the tourism industry is considered by local government as a feasible method by which to preserve Hakka culture. When other major tourism areas in the center of Taiwan were damaged by the 9.21 earthquake which occurred in 1999, Beipu drew public attention and was gradually transformed from a simple and traditional settlement into a famous and popular choice of tourists.

Previous research efforts

The preservation of Hakka culture has attracted public attention in recent years, and as building preservation has become an important issue, most efforts and resources are derived from government support. Beipu is the most representative and well-preserved settlement; however, some of the maintenance efforts come from local people and non-profit organizations. While most of the historical buildings still perform their original functions, new roles as museum or salons are emerging, which would promote their special characteristics. Preservation issues include: (1) the management and integration of cultural spaces; (2) the documentation and maintenance of buildings; and (3) the preservation and recording of community life.

The Hsinchu County Culture Bureau has assisted local culture workers in the documentation, surveying and remodeling of old buildings. In order to apply new technology to the task of preservation, the Bureau invited academics to take part in a task force whose aim was to scan the environment and the buildings for future construction or historical references.

Among those preservation efforts, records created in 2D drawings have limitations in describing the relative locations of objects located in a 3D layout, based on discrete manual measurements. Active surface measurement techniques have been used since 1994 for automatic reconstruction of 3D models by joining polygon

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meshes (Turk and Levoy, 1994). This technique enables highly accurate measurements of 3D surfaces, and the development of long-range finders has also enabled laser scans of large objects (Besuner and Springfield, 1998).

3D models are used to visualize the potentially influential area as a way to identify issues or to comprehend problem characteristics in an urban region (University College London, 2009). Related visualization technologies are applied in the arts and humanities domains to facilitate research documentation, monitoring, education, etc. (3DVisA, 2009; National Park Service, 2009; Stv News, 2009; National Museum Livepool, 2009). The advantage of 3D scans is that they enable a macro view of the whole archeological site to let researchers clearly define the interrelationships among different parts, beyond the visual barrier of walls, grounds, or other obstacles (Cyark, 2009). The final registered digital model, which is made by combining scans from different angles, enables drawings to be created as plans or sections across the whole site. Basically the scan data were used for the purpose of documentation, and the drawings are typical of data extension types. 3D scans in archeology represent a typical application of an input device.

Differences exist between computer models and cloud models. The former, which use 3D application to create from scratch, usually have limited structural details. The latter, also considered as a kind of computer model, are actually rich in structural details with/out images mapped. The scanning of an exquisite hand-made model is an alternative of reinstalling the original shape in digital format when the original site no longer exists (Guidi et al., 2006).

The elaboration of scan data is moved forward when used in the reconstruction of original appearance, based on hypothesis (Oishi and Ikeuchi, 2008). The heuristics may come from archeological discoveries, literature reviews, construction methods, materials, or legend descriptions. Computation algorithms like morphing or hole-filling are used to reconfigure shape or to define missing parts.

Most of the historical buildings need long term maintenance, and any new renovation requires access to the correct drawings from previous work. The construction data should be continuously monitored for immediate or post-construction analysis after the design stage (Al and Salman, 1985; Atkin, 1986; Shih, 2002). Building conservation should start from planning, with the consideration of feasible sustainability for future management (Global Heritage Fund, 2009). Since the concern lasts for the entire life-cycle, many parties are involved. A management issue becomes even more important after the scan data are retrieved. These parties may include firms or related research interests which may modify post-construction data to discover new relationships. Management of research efforts should be planned in advance.

A life-cycle viewpoint of data elaboration should be applied before a building or a site is planned, and should be extended to include design, construction and afterwards, management. Archiving data should be a long-term effort which deserves scheduled scans to specifically discover and quantify the possible changes caused by weather or earthquake (Barton, 2009). Archiving post-construction shapes in digital format is a typical 3D scan application which is usually conducted along with certain check points of the cycle. The scan-related life-cycle data elaboration should be broadly extended so that the changes of shapes or displacements can be monitored chronologically.

Research purpose

The purpose of this post-construction 3D scan of the historical settlement is to develop an application framework and reference with which to integrate research results from all involved parties, to serve local practical needs, and to represent the hypothesis in city development. This study is based on a 3D computer model of Beipu Township, Taiwan, as an effort to digitally preserve the cultural assets from the viewpoint of life-cycle management.

Data capture methods

This project was conducted from November 1, 2007 to September 30, 2008. The original scope was limited to the seven historical buildings and the four major streets, as discrete subjects. In order to obtain the whole perspective of the neighborhoods, the entire region was first scanned to establish a spatial framework; this was followed by the more detailed scans of buildings and streets in a top-down process instead of a bottom-up build up approach. The top-down structure was then applied to the scan procedure (data capture) and the structure of data sets.

3D scans are considered as a non-intrusive technology; therefore, areas blocked by other objects can only be created from scans of other orientations. The key challenges are to obtain data from different orientations in an over-crowded neighborhood and in the mean time have the density high enough to reveal appearance for all of the settlement. An 8–10 mm distance exists between two points for courtyards and exterior scans, for near and distant scan locations. Rooftops or balconies with higher altitude were chosen primarily as locations for regional scans, ahead of discrete building and street scans which were mainly done on ground level, traversing to lower level of hierarchy. This approach was very useful when viewing angles, and scan angles were very restricted inside narrow alleys or next to high walls, where only the roof of tall buildings can be seen from the higher scan hierarchy.

Scans were created individually or registered into a large project by referring to targets (or registration points, tie-points). Each scan has a tolerance of 6 mm/50 m (2 mm/50 m in face model). Instead of free-standing targets on tripods, building features were used for cloud registration which turned out to be very accurate. The targets were mainly located on the perimeter. Since the whole region was registered first, discrete subjects located inside have higher interpolated accuracy; in addition, the scans were made in a much shorter distance on ground level. The regional scans and discrete scans were registered and inspected in the laboratory. Missing parts were captured continuously. As result, post-construction point models were created with the visibility of details like electrical wires above the streets and the hills behind the temple.

This study applied a long-range (300 m) 3D laser scanner, the Cyrax 3000™ (see Fig. 1, right), for continuous data retrieval, instead of using traditional discrete and manual data survey method. The system applies "time of flight" method which has Cyclone 5.5™ software for scanner control and data manipulation. A Class B laser was used, with the distance measured by the differentiation of time-of-flight between the scanner and the target. The laser scanner projects laser dots in a range of $360 \times 270°$. The actual density can vary depending on the distance specified between two adjacent dots at a certain range from the scanner. The laser dots in a scan or registered scans form a "point cloud" which is represented in terms of scanworld, or scans with exported data containing x-, y-, and z-coordinates and attributes, such as intensity or color.

Scan hierarchy

The scan process was managed in four hierarchies: the whole region, the seven historical buildings, the four streets, and the special features, in order to schedule digital preservation in different scales (Fig. 2). The combinations of the hierarchies contributed to an integrated view with individual subjects scanned and organized