The Application of Reverse Engineering for Building Construction Management

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This research utilizes a 3D laser scanner to retrieve 3D digital information of a building construction site for the management purpose. The concept of reverse engineering is applied as a method in revealing potential problems in building construction process through the analysis of 3D data. This study presents construction images, scanned point-cloud sets, and output rapid prototyping (RP) models as exemplification.

***Keywords**: reverse engineering; 3D laser scanner; 3D printer; building construction management*

Introduction

Traditional building construction process represents a sequential working flow defined by working drawings for a constructer to implement step by step. If the implementation is properly planned, the whole construction could be controlled by the schedule and drawings. However, design may still subject to modifications. Unpredicted problems or mistakes might occur and cause the progress delay of the subsequent tasks. In the site, the original concepts of building construction usually end up with conflicts, resulting in design changes or an improper implementation of construction resources. By building up a 3D environment, examination or self-critiquing of the process becomes feasible.

Since the beginning of construction process, reality may depart from original plan. For example, measurement must be confirmed repetitively. The checking procedure is tedious and manpower-consuming, let along the obstacles that prevent an easy access to the locations for conducting measurement. This difficulty leads to an inaccurate construction situation that deviates subsequent correction process. Construction quality is hence affected. Therefore, the application of 3D construction scan would be very helpful in truly displaying the state of the building for facilitating self-criticism of future planning or design changes.

In final construction operation, construction managers usually discuss with architect referring the completeness of a task based on their experiences. But in reality, construction site is a very complicated environment and is located far away from main office to conduct a thorough or real-time discussion such as the situation of bad site landforms. Deviation from the design might result in changes in construction process. It is very important to scan the site to retrieve the 3D environment model to obtain a complete and exact geometric description. Therefore, this paper presents an application of a 3D laser scanner under the concept of reverse engineering to review the construction process and design changes in a 3D environment.

The concept of reverse engineering used to be applied in mechanical engineering and industry design [Ingle, 1994]. Architectural application has been used in concept visualization [Ryder, 2002], [Wang, 2002]. The limited scan size and range prevents a small RP machine from being applied in the scale of building construction management. Now the 3D laser scanner has widened the range of measurement to make the application in construction feasible.

It is also possible to review construction by reverse engineering process. Printing a 3D scanned object with a 3D printer could help analyzing potential problems and revealing details for better solutions and formulation of construction strategies.

The application of a 3D laser scanner in building construction management

The 3D laser scanner applied in this study can reach a range up to 100 meters with the deviation less than 6 mm. By casting the laser beam on building surface, the boundary of the building is captured as a 3D point-cloud model that is then converted to 3D surface model with conversion software for any further processing like creating physical RP models.

Building construction process includes many items that require repetitive reviews and simulations. In the past, people accomplish the construction based on their experiences. Simulation requires data from past experience to make computing of the result possible. But the environment in a construction site is complicated and involves many routine works and variables. It's impossible to complete the whole simulation in just one process. This study scans the 3D environment of an existing construction site to build up a physical 3D environment model. The model is then used to analyze and review construction process.

As the 3D site model has been built, it is easy to monitor more construction information and to manage construction site in details. For example, around the construction site there are structures and obstacles (such as viaduct, high voltage tower, landscape, etc.) that might effect the hoisting operation of the building construction. If we scan construction environment in 3D and simulate the site accordingly, it is possible to foresee the construction condition in advance, and plan for a best outcome.

In the construction process, construction problems are usually encountered due to inaccurate measurement and inadequate consideration of original design. If we use 3D scanner to scan the location of the problem and modify the 3D model as design specified, it could facilitate analysis and guide follow-up process. This is different from the traditional construction manner where pictures are usually taken for analysis, and the original drawings are studied to determine the solution of the problems. Whether the restricted conditions and environments produce further limitation to the problem remains to be alerted, using 3D scan to obtain information of construction condition represents a direct retrieval of the cause of problems. The data is complete and can be fully presented to the site manager to make judgments, and the ideal improvement strategy can be proposed.

During the study, some problems were encountered with the 3D scanner: 3D scanner may have several blind spots. As the 3D graphics are obtained by collecting the reflections from laser beams, some obstacles (such as buildings, trees, and hedge, etc.) or the scanner itself could be blocked and cause the scanned object incomplete. Several scans have to be made and registered into a whole. For some orientation-specific features, one scan is enough for a RP output of its shapes.

The application of building construction management with 3D printer

3D printer uses layering method to pile up in building volume into a 3D model. It is different from traditional handmade modeling process that takes effort to construct the body and to simulate the appearance of the building in details. The complicated operations are very time-consuming. A 3D printer outputs a 3D model based on the digit model from the virtual world. It can output the data according to the scale and color information of images. It is more realistic, but subjects to the output size of the machine. At this moment, the printer can only print the footage of A4 size. And due to the powder and binding process, fine details might be broken, affecting the completeness of the model.

A 3D printer facilitates the recovering of original 3D objects. For example, a 3D printer could print the images in scale after using a 3D scanner to scan an object. Original appearance is reproduced. The object can be inspected through real model by taking a portion from 3D point-cloud to record and study the building process. In addition to be inspected from computer screen, it can show any viewing angle as desired. Fig. 1 (top) shows two photos of excavation stages. Two isolated sections of the retaining wall sections, as indicated by while frames, are cut from scanned data and printed by RP machine (see Fig. 1 bottom). The physical models are used for record purpose. The difference between the two stages

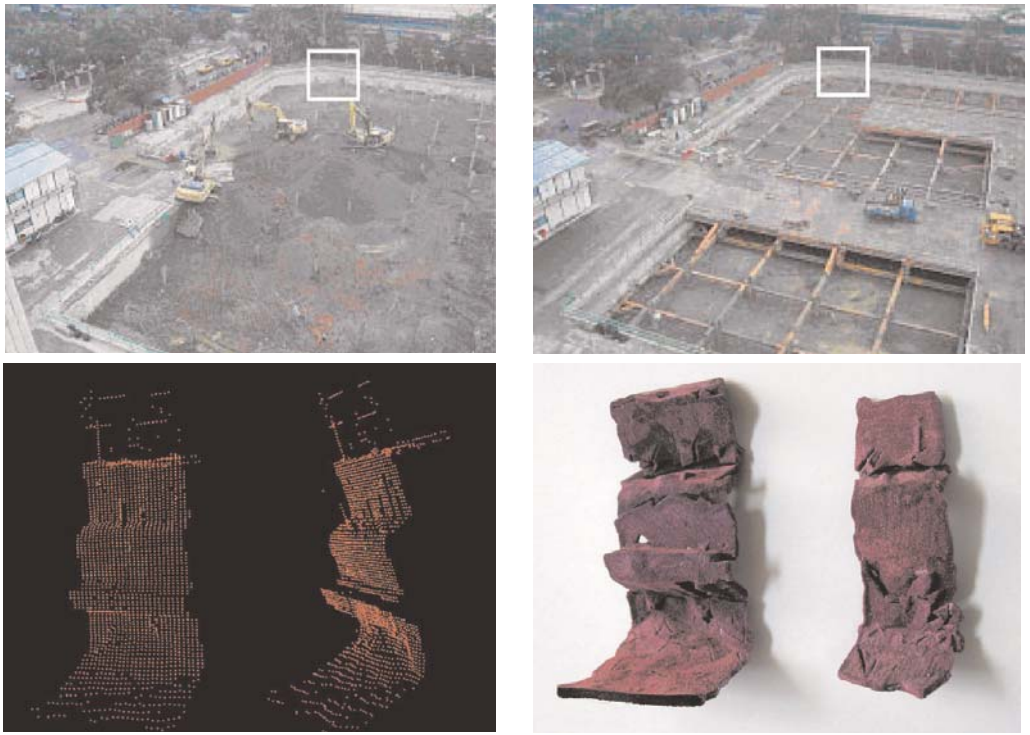

Figure 1. Two excavation photos (top) and point-cloud (bottom left), and RP output (bottom right)

is the presence of steel beam, which is shown in the point-cloud and to the left of output models. The model to the right of out models is used for reference purpose.

In the past, when the problem occurs in a construction site, there is only one viewing angle to observe the problem if only one picture is taken. But in many occasions the problems are very difficult to be spotted at the right moment. Unless the monitoring operation at construction site has been activated for a long time, the image information is not sufficient to make sound judgment. With the assistance of RP machine, the scanned data could assist construction managers to spot the cause of the problem with substantiated computer models.

The RP system is Model 406 fromZ Corporation. The machine can map color to the model surface. The retaining wall model was extruded from the mesh converted from the point-cloud to gain thickness. The final model was stored in VRML format before being sent to RP machine.

Summary

Traditional construction management depends on the experience of managers to determine the cause of actions. The objective judgment of information and attribution is in great demands. This paper discovers that, by using a 3D scanner to retrieve operation-related construction information is useful for keeping records, problem analysis, and multi-orientation inspection of details.

Management of building construction from reversed engineering process is seldom conducted in the past. One of the reasons is the limitation and the availability of tools. Now with the aid of 3D scanner and 3D printer, we believe that building construction in future can be managed from a more substantiated perspective, as a new extension to the traditional construction management.

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